The Effects of Object Ownership Status on Action

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Abstract

Ownership, a sociocultural concept experienced at an intrapersonal level as thoughts and feelings than an object is *mine*; is an important feature of our daily experience. However, norms and laws define our behaviour in response to others' belongings. Research is beginning to elucidate that the ownership status of an object, whether an object is *mine* or *yours,* influences a range of cognitive processes. Findings generally indicate that objects associated with the self receive prioritised processing, compared with objects associated with others. However, within the lesser investigated cognitive domain of action production, there is some initial evidence to suggest that we are sensitive to other's belongings; with knowledge of self *and* other-ownership modulating the visuomotor system. Therefore, the present thesis aimed to extend these findings in two key ways. Firstly, on the basis of indirect evidence obtained from movement kinematics, by investigating whether ownership mediates the tendency to approach or avoid objects. Secondly, by investigating the influence of ownership status in an action context yet to be considered: during the avoidance of obstacles within the workspace.

Broadly, this thesis presents findings consistent with indirect evidence that ownership status does influence approach and avoidance behaviour; and evidence that the visuomotor system possesses some sensitivity to the ownership status of obstacles as we navigate the workspace. However, in accordance with previous work, the effects obtained, particularly in relation to other-ownership, were sensitive to task context. In addition, alternative explanations of self-ownership effects (for example, resulting from attentional mechanisms) were difficult to fully discount using indirect measures, such as response time. Therefore, while adding to the limited body of research concerning the effects of ownership on the visuomotor system; the current work highlights the need for future research concerning motoric effects to recruit more direct measures of action-related processes.

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Chapter 1. Introduction

When I get up in the morning, I make coffee in my mug, eat my bagel while checking my phone for my emails, drive my car to work, and log on to my computer to work on my research project. When I attend a meeting, someone is sitting in my seat. I do not legally own it; it is the property of the university, but I have feelings that it is mine. I always sit there. Someone mentions an idea that I talked about only last week; and that instantaneous feeling of theft of my idea arises. Ownership is a guiding principle of thought and behaviour, and attesting to its importance, scholars have long theorised about the origins, functions, and consequences of personal property for man (e.g., James, 1890; Locke, 1690; Sartre, 1943). Recently, there have been attempts to synthesise the wealth of literature to create a coherent account of ownership (see Pierce, Kostova, & Dirks, 2003). However, such work has largely relied on observations and anecdotal descriptions of ownership experiences. More recently, across numerous disciplines (e.g., consumer behaviour, behavioural economics, and developmental psychology), there has been increased interest in empirically investigating ownership. The first half of this review will conceptualise ownership, firmly situating theoretical concepts about its function and development alongside empirical findings.

Despite longstanding interest in how self-relevant (e.g. own name, own face) stimuli influence cognitive processes, such as attention and memory, investigation concerning how ownership is represented and processed at a cognitive level has remained relatively slow to emerge. During the past decade, there has been a surge in findings concerning the cognitive treatment of objects associated with the self, albeit, often utilising objects arbitrarily and temporarily associated with the self to extend knowledge regarding self-relevant biases in general. Such research has started to inform understanding of how cognition is performed for self-object associations. However, consideration of the cognitive treatment of objects belonging to others remains relatively understudied, with other-ownership often being treated as merely a less salient comparison condition to illustrate superior self-object processing. Other-ownership possesses social importance, as it determines what we are permitted to do (or not do) with someone else's property. To act appropriately in a social world full of owners, we must also reason about others' property, and respect others' rights. Therefore, research concerning ownership must also account for how we behave in relation to objects belonging to others, alongside biases associated with our own property. Therefore, the second half of this review will analyse work concerning biases elicited by self-associated objects, and examine the small body of work pertaining to whether the action system displays sensitivity to other-ownership cues.

Conceptualising ownership

Ownership, which can be broadly defined at an individual level as experiencing an object as *mine* (Pierce et al., 2003), has historical longevity as an aspect of lived experience, dating back at least as far as 100,000 years (Leaky, 1981; Marginer, 1960). Tendencies for ownership are enduringly cross-cultural (Hobhouse, Wheeler & Ginsberg, 1915; Webster & Beatty, 1997), although, despite economic globalisation and Westernisation, the experiences and effect of ownership may still differ across cultures (for example, the possessions most valued; Watson, Lysonski, Gillan, & Raymore, 2002; the effects of ownership on object valuation; Maddux et al., 2010). Attesting to its importance as a governing construct of our lives, children exhibit attachment to objects, such as blankets, from at least six months of age (Furby & Wilke, 1982; Lehman, Arnold, & Reeves, 1995), and begin to use self-related possessive pronouns (mine) in conversations with peers to express ownership, from around eighteen months (Bates, 1990; Hay, 2006).

Despite possessing a tacit sense of what it means to own, operationalising ownership is not simple. Ownership extends beyond physical possession of a thing, remaining when we are not executing control over the object (Stake, 2004). It is part real (i.e. the object) and part individual (experiencing an object as *mine*; Pierce et al., 2003). However, ownership is also social; the notion of ownership arises from a sociocultural landscape that acknowledges the concept of, and possesses norms and laws governing, ownership (Bentham, 1914; Etzioni, 1991; Snare, 1972). Ownership defines how ourselves, and others, behave in relation to property we own, and reciprocally shapes appropriate responses to other's belongings. In any discussion of ownership, the distinction between ownership ascribed by law, and the experiential state of ownership (commonly referred to as psychological ownership; see Pierce, et al., 2003), must be highlighted. Ecologically, legal and psychological ownership are often confounded. However, psychological ownership can develop for physical objects in the absence of legal ownership (for example, see Peck & Shu, 2009; Reb & Connolly, 2007).

When considering what is subject to ownership claims, most frequently, a sense of psychological ownership is experienced for physical objects (Isaacs, 1933; Prelinger, 1959); from consumables (Ellis, 1985), through to more treasured family heirlooms and mementos (Curasi, Price, & Arnould, 2004). However, we frequently extend expressions of ownership beyond objects that can be manipulated, to ideas and space (Brown & Robinson, 2011), our workplace (for example, see van Dyne & Pierce, 2004); and even sounds (Isaacs, 1933). However, the degree of the bond experienced for possessions varies (Kleine, Kleine, & Allen, 1995; Kleine & Baker, 2004). Therefore, some have argued for a distinction between attachment to objects (a sense that the object is 'me', with the owner curating a deep emotional bond over time; Kleine et al., 1995), and psychological ownership (a feeling of mine; for a review of material possession (attachment), see Kleine & Baker, 2004). Certainly, it is intuitively logical to view feelings of ownership as a continuum. Experiencing the same experiential sense of ownership for a disposable pen as we do for our treasured childhood teddy bear would cause undue distress on every occasion that one is appropriated from our desk by a colleague. Hereafter, this review focuses on the development and consequences of psychological ownership, although often confounded with legal ownership in laboratory settings, for everyday items.

Ownership as object

As discussed, the entities for which we experience ownership are diverse, and identifying objects subject to feelings of ownership is uninformative about its development and consequences. Rather than aim to taxonomise objects possessed, research has sought to quantifiably measure the elicitation of ownership, and the effect this has on object evaluations.

Ecologically, we tend to choose what we come to own. While choice does mediate object valuations of owned objects (Huang, Wang, & Shi, 2009), simply endowing someone with an object in the absence of choice is sufficient in producing biased evaluations for the item. For example, arbitrarily assigning participants ownership of a reasonably low-worth item in laboratory settings (for example, a pen or drink sleeve) produces explicit and implicit preferences for the self-object, relative to unowned and others' possessions (Beggan, 1992; Beggan & Allison, 1997; Huang et al., 2009; Nesselroade et al., 1999; Nuttin, 1987; Yeung, 2012). This finding, dubbed the *mere ownership effect* (Beggan, 1992; Nuttin, 1987), has been observed for both physical objects (Beggan, 1992; Nesselroade et al., 1999; Huang et al., 2009; in children, see Gelman, Manczak, & Noles, 2012), and non-tangible 'objects', such as arguments (De Dreu & van Knippenberg, 2005).

Another measure that appears to serve as a proxy for, and may result from (Morewedge, Shu, Gilbert, & Wilson, 2009), ownership, is monetary valuation. In paradigms exploring economic trading behaviour, some participants are assigned an object (for example, a mug or pen; Kahneman Knetsch, & Thaler, 1990; Shu & Peck, 2011), with the option to sell during the experiment. Participants assigned the item specify the price they would be willing to accept to sell the object (willingness to accept; WTA), while others not given an object indicate the value they would pay in order to acquire it (willingness to pay; WTP). Contrary to 'rational' economic rules, sellers frequently demand larger monetary amounts to surrender the item, compared with prices offered to acquire it (e.g., Kahneman et al., 1990; Kahneman & Tversky, 1984). Even imagining being given an object is sufficient to produce this effect (Carmon & Ariely, 2000).

This pattern of behaviour, termed the *endowment effect* (Thaler, 1980), has been robustly replicated using many types of objects such as; lottery tickets or entries for a draw (Casey, 1995), event tickets (Adamowicz, Bhardwaj, & Macnab, 1993), chocolate (e.g. Knetsch, 1989; Reb, & Connolly, 2007), and wine (van Dijk & van Knippenberg, 1998; for a review, see Horowitz & McConnell, 2002). Endowment effects also occur for intellectual property, such as creative work (Buccafusco & Sprigman, 2010; Buccafusco & Sprigman, 2011). However, some have questioned whether the WTA-WTP gap is a result of task procedures producing participant misconceptions (Plott & Zeiler, 2005; However, see Ladner, Loomes, & Sugden, 2011).

Traditionally, this effect has been attributed to loss aversion (for a review of all alternative theories, see Morewedge & Giblin, 2015); that individuals experience losses (vs. the status quo) as more painful than gains. In the case of buying and selling goods, relinquishing an object as a seller is considered a loss, whereas receiving an object not owned is a gain for the buyer. Therefore, sellers require more monetary reimbursement to do so (Kahneman et al., 1990; Novemsky & Kahneman, 2005; Thaler, 1980). However, the task procedure regularly confounds ownership, with sellers owning the endowed items, and buyers being non-owners. Therefore, akin to the mere ownership effect, increased monetary valuations may result ownership contributing to avoidance of losses due to loss of ownership (Chatterjee, Irmak, & Rose, 2013).

In support of an ownership account of the WTA-WTP gap, Morewedge et al. (2009), observed that those buying a mug who already owned one (owner-buyers), offered similar prices to owners selling (owner-sellers), in contrast to buyers who did not own a mug, offering the lowest price to acquire one. In addition, owner-buyers were willing to pay more to acquire an item when purchasing on behalf of another, relative to non-owner buyers, and compared with what non-owner sellers required when trading for another individual. Such findings support an ownership account of the endowment effect; as loss aversion assumes owner-buyers would behave like regular buyers, and sellers would always demand higher prices than buyers (also see List, 2003; Peck & Shu, 2011). In summary, assigning ownership of an object increases owner's preferences and valuations of the item, relative to unowned items.

Although merely being assigned an object appears sufficient to produce a sense of ownership, indexed via increased evaluations, specific object-based experiences can also drive its development, particularly in the absence of legal ownership. The 'routes' to ownership have long been of interest to scholars (e.g., James, 1890; Sartre, 1943). Pierce et al. (2003), synthesised the routes to ownership proposed in previous literature into three main processes: control (e.g., Furby, 1978; McClelland, 1951; Rudmin & Berry, 1987; Sartre, 1943), familiarity (Furby, 1978; James, 1890; Rudmin & Berry, 1987), and creation or investment (e.g. Belk & Coon, 1993; Locke, 1690; Sartre, 1943). Recently, progressing beyond attempts to merely quantifiably measure the effects of, often legal, ownership on valuations in endowment research; studies have attempted to empirically identify mechanisms through which psychological ownership develops; albeit often using object valuations as outcome measures.

For example, potentially supporting control as a route to ownership, Peck and Shu (2009) found that briefly touching an object increased feelings of perceived ownership; compared with those who could view the object for the same length of time but were not permitted to interact with the item (see also Reb & Connolly, 2007). In addition, the length of time an object is owned influences the owner's financial valuation of the item (Strahilevitz & Loewenstein, 1998; see also Peck & Shu, 2011). Although not a direct measure of familiarity, repeated exposure to objects increases familiarity, and may therefore underlie this temporal effect. Furthermore, in a study that more directly manipulated familiarity, Wolf, Arkes, and Muhanna (2008), found that more time spent examining objects, prior to making offers, increases the price buyers are willing to pay for an object; suggestive of feelings of increased ownership.

Finally, there is also accumulative evidence to support the role of creation and investment of labour in feelings of psychological ownership. Studies have found that participants are willing to pay more for items they have assembled (Norton, Mochon, & Ariely, 2012), or designed (Franke, Schreier, & Kaiser, 2010), compared with the WTP for those who have not invested labour. Creating poetry and art also increases the creator's monetary valuations, compared with valuations offered by those who merely own, but did not create, them (Buccafusco & Sprigman, 2010; Buccafusco & Sprigman, 2011). Therefore, processes such as touch and familiarity serve to increase feelings of psychological ownership, particularly in the absence of legal rights.

Ownership as individual

As discussed, we express feelings of ownership for numerous forms of objects. Coming to own an object increases our monetary valuation of it, and its favourability. Although purely being endowed with an object appears to produce a degree of psychological ownership, mechanisms such as choice, control, familiarity, and investment with the object, facilitate its development. However, focus on the outcomes does not elucidate *what* ownership means at an individual level, nor *why* we own.

At an intrapersonal level, ownership can be envisaged as a connection between the self and an object (Litwinski, 1942; Wilpert, 1991). However, this relationship between person and thing is proposed to extend beyond objective knowledge of having ownership. Notions of ownership as a merging of who we are and what we have; a combining of 'me' and 'mine' are persistent (for example, see James, 1890; Sartre, 1943; Belk, 1988). Therefore, ownership can perhaps be conceptualised as thoughts and affective states, that a target object is 'mine' (Pierce et al., 2003), with that object not only connected to the self through owning, but coming to be part of the self (Belk, 1988).

It is proposed that this combining of mine and me results from acquiring and possessing objects with self-congruent meanings and values (either reflecting our personal identity, or social identity; Tajfel & Turner, 1979). In line with this, individuals report owning more items related to their identities, such as 'athlete' (Kleine, Kleine, & Kernan, 1993). When considering consumer preference, people favour brands congruent with their perceived identity (e.g., Escalas & Bettman, 2005; Chan, Berger, & Boven, 2012); and avoid acquiring items associated with group identities with which the buyer does not feel affiliated (Berger & Heath, 2007).

However, the development of self-object associations at a cognitive level may be more simplistic. Implicit measures of construct association reveal faster responses for self-related word stimuli when preceded by an object for which they had been assigned ownership at the start of the experiment; relative to response times when primed by an object not owned (Ye & Gawronski, 2016; also see LeBarr & Shedden, 2017). This finding suggests that individuals 'instantaneously' associate objects that have been assigned with the self. At a neural level, thinking about owned objects increases activity in brain regions linked to self-related cognition (medial prefrontal cortex; see Kim & Johnson, 2012), illustrate neural connectivity between the 'self' and possessions. In cases where ownership is not explicitly granted, touch and investment of labour may assist in creating a self-object association.

Providing further support for the ease at which objects become associated with the self, the increase in explicit valuation of an object upon being endowed with it, is assumed to result from the positive self-evaluations individuals hold about themselves, and their motivations to maintain their positive self-concept. Just two examples of the positive bias people exhibit regarding the self, include; judging themselves as performing better than others when grading their performance (e.g., John & Robins, 1994), processing positive self-relevant information faster, and recalling more positive than negative self-attributes (Kuiper & Derry, 1982; for a review of self-enhancing biases, see Sedikides & Strube, 1997; Pelham, Carvallo, & Jones, 2005).

Illustrating the connection between positive self-concept and ownership, studies have aimed to 'damage' individuals' sense of self, through methods such as negative task feedback (e.g., Diesendruck & Perez, 2015; Sivanathan & Pettit, 2010) and interpersonal rejection (Dommer & Swaminathan, 2012), to observe the effect on object valuations. Individuals often seek means to enhance the self after self-threat (e.g. Argo, White, & Dahl, 2006), further increasing valuations of self-owned items may help to bolster the self. Such manipulations commonly increase individual's selling prices (Sivanathan & Pettit, 2010; Dommer & Swaminatahan, 2012; although see Walasek, Matthews, & Rakow, 2015), or decrease the willingness to part with valued possessions (Diesendruck & Perez, 2015; also see Morrison & Johnson 2011; Keefer, Landau, Rothschild, & Sullivan 2012).

In addition to becoming associated with the psychological 'self', possessions may extend the physical self. Acquiring objects with instrumental functions allows us to act upon the environment in ways we would otherwise be incapable (Belk, 1988; Furby, 1978), for example, our hammer allows us to drive the nail into the wall. At a cognitive level, tools influence our perception of the environment; making objects that fall outside of arm's reach appear closer to the body when we intend to touch them with a tool, vs. without the tool (e.g., Witt, Proffitt, & Epstein, 2005). Similarly, tools extend what is experienced as near space (e.g., Longo & Lourenco, 2006). Therefore, although ownership is not required to garner such effects, objects also facilitate a greater sense of ability to act upon the environment, physically extending our sense of self.

Ownership instinct?

At the individual level, ownership appears to be experienced as a connection between the self and an object. However, findings that objects become associated with self do little to explain the genesis of our drive to acquire property. Some purport that ownership functions as an innate adaptive mechanism serving survival (for example, see Ellis, 1985; Hare, Reeve, & Blossey, 2016; Litwinski, 1942; Stake, 2004). Evidence cited to support this notion is drawn from findings that numerous species such as, butterflies (Davies, 1978), finches (Senar, Camerino, & Metcalfe, 1989), wasps (Eason, Cobbs, & Trinca, 1999), and non-human primates (Ellis, 1985) exhibit possessive behaviour over territories when challenged by others seeking to acquire it. However, such findings only allude to the propensity for possession. Although possession and ownership are interconnected, ownership extends beyond possession, requiring others to respect another's resource (Hare et al., 2016), even when it is not within their physical possession (Brosnan, 2011).

However, there is substantially less cross-species evidence of respect of possession. Non-human primates do exhibit some degree, for example, non-owner baboons do not attempt to acquire a can of food from the possessor when they had observed the owner eating it (Sigg and Falett, 1985; for other examples of primates respecting possession, see also Kummer & Cords, 1991; Russ, Comins, Smith, & Hauser 2010). Also eluding to the concept of ownership in non-human primates, chimpanzees, like humans, exhibit the endowment effect, more greatly valuing an object given to them, measured by a reticence to trade for an alternative (Brosnan et al., 2007; Brosnan, Jones, Gardner, Lambeth, & Schapiro, 2012; for evidence in capuchin monkeys, see Lakshiminaryanan, Chen & Santos, 2008). However, this effect in chimpanzees only occurs for endowments that have ecological value, such as food (vs. tokens; Brosnan et al., 2007), and for tools only when they can be used to reach food (vs. when the food is unobtainable with the tools; Brosnan et al., 2012).

Beyond instinct

For humans, it is likely that property acquirement extends beyond adaptive instinct to secure resources to survive; we acquire more than we need to purely survive, and in contrast to the evidence available from other species, experience ownership for objects that do not serve survival and may not even be tangible.

In addition, ownership as a construct is mediated by sociocultural differences. For example, the endowment effect appears to be culturally mediated, with increased seller's valuations, relative to buyer's offers, absent for East Asian participants (vs. Westerners). Furthermore, when independent self-construal was primed in the East Asian sample, the endowment effect was observable (Maddux et al., 2010). As discussed, increased valuations (e.g., Morwedge et al., 2009) and preference for endowed objects (e.g., Beggan, 1992), are assumed to result from self-enhancing biases (for a review, see Sedikides & Strube, 1997; Pelham et al., 2005). In Eastern cultures, self-enhancement biases are generally observed to be absent or reduced (for example, see Heine & Hamamura, 2007; Markus & Kityama, 1991).

However, it must be noted that the notion of self-enhancement being absent in East Asian samples is contentious (see Sedikides & Gregg, 2008). Alongside findings that East Asian samples display self-enhancing behaviour in relation to highly valued cultural norms (such as modesty; Cai et al., 2011), the cultural emphasis on modesty and not being 'boastful' may mediate the explicit expression of overt self-enhancing behaviour, rather than represent a lack of self-enhancement behaviour (Cai et al., 2011). Such findings do, however, indicate that ownership experiences, or at least their explicit expression, are mediated to a degree by cultural practices and social norms.

Ownership as social: Beyond 'mine'

When considering ownership, much research has focused on the experiences and effects of self-owned property, neglecting the social component of ownership. Ownership at the individual level may involve a connection experienced between person and object; although the experience may vary as a product of sociocultural experience. However, ownership is also interpersonal, requiring agreement between people (owners and non-owners), in relation to an object (Singer, 2010). Ownership can only be maintained through others' respect for ownership claims (Rose, 1985).

For ownership claims to be respected, they must be made for objects (physical or non-physical) that others consider to be 'ownable'. We may experience a sense of ownership for something, but if others do not collectively agree that the item is subject to ownership claims, we do not own it. Although we normatively accept ownership claims for material objects, there is evidence that both adults and children also routinely accept claims of ownership extended to ideas. However, we do not accept ownership for all entities; such as common words (Shaw, Li, & Olson, 2012; also see Olson & Shaw, 2011).

Further to collective agreement of what can be owned and shared understanding what ownership means, such as the rights the status of ownership bestows upon the owner, for example rights to use and control other's use (Snare, 1972), is also required to maintain the construct of ownership. An object being 'mine' means I have the right to use it, even when I am not in current physical possession, and you do not have the right to use it. An object being 'yours', means I have no right to act upon it. If ownership did not confer the owner with entitlement over the object, its communication would be meaningless. Without the entrenchment of such sociocultural understandings of ownership, and respect for this framework, there are just objects and people; who may physically possess something at a moment in time, but have no claims over it. In turn, while others should respect our ownership claims, we must also adhere to norms to respect the possessions of others. As developmental psychologists are greatly interested in how children reason about abstract ideas (e.g. others' mental states, moral concepts), the abstract nature of ownership understanding has resulted in much research concerning this process being conducted with children.

Developing understandings of ownership rights

Attesting to the social nature of ownership and its dependence upon the respect of others, observational methods frequently report conflicts between children over objects during play (e.g., Shantz, 1987; Ross, 1996). However, children begin to demonstrate knowledge of ownership rights and use them to settle such disputes from an early age. From two years of age, children appeal to ownership as grounds for settling disputes about who has the right to interact with an object (Ross, 1996; Neary & Friedman, 2014; also see Nancekivell & Friedman, 2014). Similarly, children protest at another violating their own property rights (someone taking their object or throwing it away), from around two years of age, before beginning to challenge a violator of other's rights at around three (Rossano, Rakoczy, & Tomasello, 2011; see also Schmidt, Rakoczy, & Tomasello, 2013). Children are also sensitive to more subtle elements of ownership rights, such as owner's approval (indicative of consent, or lack of) of other's interactions, when considering whether property rights are violated. Children evaluating others' interactions with property that resulted in negative responses from the owner considered such behaviour as less acceptable, compared with object interactions that elicited a positive response. However, the approval or disapproval of a non-owner when the owner interacted with the object did not influence judgments (Van de Vondervoort, & Friedman, 2015).

Such examples of children's understandings of ownership rights only consider cases where ownership by one party is undisputed, and the associated rights are violated. Children also develop sophisticated reasoning concerning who should be assigned ownership in disputes about the owner. A cross-cultural study on children aged three to five years required them to decide who owned an object during a dispute between two individuals. Children favoured creators of objects as owners, and were more likely to assign ownership to someone familiar with an object. This finding was observed across children from different cultures; comparing children from the United States, Brazil, Vanuatu and China (Rochat et al., 2014). As discussed, creative labour is a long cited route to ownership development (e.g. Locke, 1690), and social emphasis is also placed on creation as source of legitimate ownership claims (see also Kanngiesser, Itakura, & Hood, 2014). Therefore, children appear to develop normative reasoning regarding ownership from an early age.

The lack of differences observed in Rochat et al.'s (2014) cross-cultural study of ownership attribution is, perhaps, surprising. Given that our ideas of ownership are proposed to be socially situated, we would anticipate differences, especially when comparing children from rural areas with egalitarian values; such as those living in Vanuatu, with children from urban, individualistic areas, such as the United States (Rochat et al. 2014). Therefore, the basis on which we reason ownership may be broadly similar across cultures. However, one finding that signaled subtle differences in resolving ownership disputes was the Chinese children's more frequent recruitment of splitting an object, rather than assigning to one individual. The authors attribute such behaviour to the emphasis placed on sharing and the collective within the Chinese children's preschool environment in line with the interdependent self-construal (vs. independent) commonly observed in individuals from Eastern cultures; with the self-defined as relational (Markus & Kitayama, 1991). Other research observes increased levels of spontaneous sharing amongst Chinese children (Rao & Stewart, 1999), when compared with American children (Birch & Billman, 1986), potentially supporting the splitting of resources observed.

To respect other's ownership of physical and immaterial property, and its associated rights, we must infer who owns something. Unlike other characteristics of objects, such as shape and colour, ownership cannot be directly perceived through object observation.

Inferring others' ownership

One central way in which we establish ownership is through others' language use, attending to the use of first, second, and third-person possessive pronouns (e.g. 'my' mug, 'your' pen, 'their' watch), when people refer to objects. Children develop the ability to *use* possessive pronouns to communicate ownership from approximately 18 months of age (Bates, 1990; Hay, 2006), and can distinguish between objects belonging to themselves and to familiar others (Fasig, 2000). However, children may possess some *comprehension* of others' use of possessive pronouns from around twelve months (Saylor, Ganea, & Vázquez, 2012). Although children do not reliably accomplish correct attribution of ownership based on verbal information in more complex scenarios, such as keeping track of verbal information concerning ownership (own and researcher's) while objects are spatially repositioned (Gelman, Manczak, & Noles, 2012), and in the presence of conflicting physical cues (Blake, Ganea, & Harris, 2012), until later.

Verbal cues about ownership are an important basis for inferences, but they are not always available. Therefore, in some scenarios, we must rely on other information when attempting to identify object ownership. Developmental research suggests we possess a range of heuristics to assist in ownership attribution. When observing actors manipulating objects, one principle adopted by adults (Friedman & Neary 2008a), and reliably in children from around three years of age (Friedman & Neary, 2008b), is to attribute ownership to the first individual we witness possessing it. Possession may act as a cue from which to reason about the history of ownership. For example, when presented with information about object history, such as child A bringing an object to the park, but child B playing with it before Child A, children were more likely to select Child A as the owner, overriding the first possession heuristic (Friedman, Van de Vondervoort, Defeyter, & Neary, 2013; also see Kanngiesser et al., 2014).

When other information is available, children also infer ownership from, arguably more complex, non-verbal cues, such as the emotional reaction of one of two parties when an object is broken (sad reaction), or fixed (happy reaction; Pesowski & Friedman, 2016). Furthermore, between four and five years, children also begin to utilise their knowledge of ownership rights during ownership attributions; assigning ownership to an individual controlling the right of others to use an object (Neary, Friedman, & Burnstein, 2009). Knowledge of whether the object is normative for the gender or age of the possible owner is also recruited heuristically, by both adults and children (Malcom, Defeyter, & Friedman, 2014). Early development of ownership understanding, and the ability to infer ownership, attests to the social importance of the need to respect owners and their belongings.

Ownership and cognition: Self-relevance

Cognitive psychologists have long been interested in whether self-relevant stimuli, such as our own names, are afforded advantages during stimulus processing (e.g., Cherry, 1953; Moray, 1959, Rogers, Kuiper & Kirker, 1977; Symons & Johnson, 1997). However, beyond the evaluative biases elicited by ownership, the cognitive basis (whether ownership alters the ways in which objects are treated by the cognitive system) has historically received little attention. This is somewhat surprising, given that self-ownership represents a form of self-relevance through which biases can be investigated. In addition, ownership is a salient feature of our environment, pertinent to object-based processing.

Biases for self-objects, such as the ability to quickly identify what is ours within the environment and remember our belongings, is paramount in protecting them from appropriation or inappropriate use by others. Given that work previously presented within this chapter suggests that at least some of our tendency to acquire objects appears to be an evolutionary mechanism serving survival and property also ‘prop ups’ our sense of self (Belk, 1988), biases for ownership have clear adaptive (Cunningham, Brady-Van den Bos, Gill, & Turk, 2013), but also psychological, benefits. Over the past decade, research has started to explore the nature of cognitive processing for owned objects; indicating that objects associated with the self do bias a range of cognitive processes, such as memory, attention, and perceptual identification in a manner akin to other self-relevant stimuli.

Memory

One of the most significant findings illustrating that the self shapes cognitive processes is the self-reference effect (SRE) in memory (Rogers et al., 1977; see also Kuiper & Rogers, 1979); the finding that individuals recall more information when related to the self during encoding, compared with stimuli encoded in relation to another. Traditionally, mnemonic advantage for stimuli encoded with reference to the self was demonstrated by comparing recall of trait words under different conditions while evaluating whether it describes the self (e.g., “are you motivated?”), compared with semantic (e.g., “is motivated the same as ambitious?”), phonemic (e.g., “does motivated rhyme with cultivated?”), and structural (e.g., “does ‘motivated’ have capital letters?”), encoding conditions (Rogers et al., 1977). Although semantic encoding produces enhanced recall when compared with phonemic and structural conditions (e.g., Craik & Tulving, 1975), the self-reference condition produces the most superior performance (Rogers et al., 1977). When extending the paradigm to compare trait adjectives encoded in relation to another (e.g., “is Donald Trump motivated?”), the self-reference advantage remained (Kuiper & Rogers, 1979; for a meta-analytic review, see Symons & Johnson, 1997).

Beyond increased recall of items encoded with self-reference, the self-condition increases the number of ‘remember’ versus ‘know’ responses (the self-reference recollection effect (SRRE); Conway & Dewhurst, 1995). Remember (i.e. can recollect specific details of the stimulus’s earlier presentation), and know (a sense of familiarity that the stimulus has been seen before), experiences are assumed to reflect two distinct aspects of recognition memory - with remember responses signaling episodic recollection resulting from elaborative encoding producing rich representations (see Gardiner & Java, 1993; Gardiner & Richardson-Klavehn, 2000; although for questioning of the states as functionally independent, see Dunn, 2008; Hockley, 2008).

It is purported by some, that the SRE arises from incoming information being related to, and enriched by, the extensive body of self-knowledge; aiding elaborative encoding (Klein & Loftus, 1988). However, the SRE can be obtained under conditions that do not require explicit evaluative encoding in relation to the self. For example, when participants merely report whether trait adjectives are displayed above or below their own, or another's, name (and face; Turk, Cunningham, & Macrae, 2008). This incidental advantage, not relying on explicit elaboration, is suggestive that ownership could also be privy to similar mnemonic advantages.

More recently, ownership has been adopted as another, more ecologically reflective, means through which to investigate less explicit evaluative self-encoding behaviour. Cunningham Turk, Macdonald, and Macrae (2008), asked pairs of participants to imagine they had won a shopping basket of items. The items won were presented on cards, to be sorted into two shopping baskets (one red, the other blue), one owned by the self, and one belonging to the other participant. Red and blue marks on the images indicated whom the object belonged to. After sorting the cards, participants completed a surprise recognition test. In accordance with the trait-adjective SRE, participants correctly recognised more self-owned items than those owned by the other participant. Beyond greater recall, self-owned items also elicited more recollection, rather than familiarity, mnemonic experiences (van den Bos, Cunningham, Conway, & Turk, 2010). This effect is robust, replicated in both adults (e.g. Turk, van Bussel, Waiter, & Macrae, 2011; Kim & Johnson 2012), and children (Cunningham, Vergunst, Macrae, & Turk, 2013).

Such findings demonstrate that recall advantages for information related to the self also extend to self-associated objects, perhaps unsurprising given the importance of being able to remember what items within the environment are ours. Findings produced from this paradigm are also informative about the nature of the SRE in general; as akin to Turk et al. (2008), there was no requirement to explicitly relate incoming objects to self-representations during the shopping task. Therefore, it is not necessarily the application of information to existing rich self-knowledge that results in the SRE, as traditionally suggested (e.g. Klein & Kihlstrom, 1986; Klein & Loftus, 1988). Instead, this 'minimal' SRE may result from biased attention allocation for self-owned property. Attentional resource availability is a prerequisite for deeper elaborative encoding of material, resulting in more 'remember' recall instances, compared with conditions where attention is divided (for example, see Mangels, Picton, & Craik, 2001; Gardiner & Richardson-Klavehn, 2000). In accordance with an attentional account, Turk et al. (2013) observed that dividing attention during the encoding period of the shopping task abolished the episodic ownership effect (greater remember responses), observed in van den Bos et al. (2010). There is a wealth of research illustrating that attention prioritises self-relevant stimuli, potentially underpinning the SRE.

Attention

The volume of incoming information experienced at any moment cannot be effectively processed simultaneously (Bargh, 1982; Allport, 1989). Therefore, elements of this vast array must be selected to receive further processing, and attention is the mechanism through which this selection occurs (Allport, 1989). Visually, attention can be guided based on salient physical properties of stimuli, such as colour (Theeuwes, 1992; Mounts, 2000), motion (Theeuwes, 1994; Theeuwes, 2010), or sudden onset (Jonides & Yantis, 1988).

However, attention allocation is also affected by top-down goals. We can be attuned to attend to certain stimuli based on prior information about their features, we can possess an 'attentional set' for certain types of stimuli (e.g., Koivisto & Revonsuo, 2007; Most, Scholl, Clifford, & Simons, 2005; Simons, 2000). We may also possess 'habitual' attentional sets for some categories of stimuli that possess meaning for the observer (those that signal threat; Blanchette, 2006; Most, Smith, Cooter, Levy, & Zald, 2007; or possess social significance, e.g., faces; Lavie, Ro, & Russell, 2003; Devue, Laloyaux, Feyers, Theeuwes, & Brédart, 2009). Self-relevant information constitutes another category of stimuli that appears to receive prioritised selection. Preferentially attending to self-relevant cues within the environment has clear ecological advantages in terms of tracking what is important for processing.

The *cocktail party* effect, the finding that (in this case, auditory) self-relevant stimuli, such as your name, can capture attention when presented in an unattended channel (Moray, 1959; Wood & Cowan, 1959), is one of the earliest findings that self-relevant stimuli possess special cognitive significance. In the visual domain, self-relevant stimuli can potentially impair performance when appearing as distractors (Wolford & Morrison, 1980; Brédart, Delchambre, & Laureys, 2006; although see Devue & Brédart, 2008), and are more likely to be detected when unexpectedly appearing in an array than non-self relevant words (Mack & Rock, 1998; although see Bundesen, Kyllingsbaek, Houmann, & Jensen, 1997).

Findings that self-relevant stimuli interfere with primary task processing has resulted in claims that self-relevance automatically 'captures' attention; that such stimuli are attended to without volition. However, inconsistencies in the replicability of such effects ultimately suggest that self-relevant stimuli may require some available attentional resources to be processed. For example, Devue and Brédart, (2008), failed to replicate primary task interference from own face distractors, observing that the interference quickly dissipates after a few presentations of the self-relevant stimulus (for other failures to observe automatic attention capture, see Harris & Pashler, 2004; Bundesen et al., 1997; Gronau, Cohen, & Ben-Shakar, 2003; Keyes and Dlugokencka, 2014).

However, although the automaticity of attention allocation to self-relevant stimuli is questionable, self-relevant stimuli are certainly subject to prioritised selection when attentional resources are available. Self-relevant stimuli interfere with processing when presented centrally (but not peripherally; Gronau et al., 2003), and are detected faster in an array when task-relevant (e.g., Harris & Pashler, 2004; Tong & Nakayama, 1999; Yang, Wang, Gu, Gao, & Zhao, 2013). Self-relevant stimuli are also accorded more processing, indexed by a larger P300 event-related potential (ERP) component; even compared with the resources devoted to processing task-relevant stimuli (Gray, Ambady, Lowenthal, & Deldin, 2004; Ninomiya, Onitsuka, Chen, Sato, & Tashiro, 1998; Shi, Zhou, Liu, Zhang, & Han, 2011; Zhou et al., 2010).

Such attentional effects have been observed across a myriad of types of self-relevant stimuli; such as own name (Alexopoulos, Muller, Ric, & Marendaz, 2012; Arnell, Shapiro, & Sorensen, 1999; Mack & Rock, 1998; Shapiro, Caldwell, & Sorensen, 1997; Tong & Nakayama, 1999; Wolford & Morrison, 1980; Yang et al., 2013), own face (Brédart et al., 2006; Ninomiya et al., 1998; Sui, Zhu, & Han, 2006; Tacikowski & Nowicka, 2010; Zhu et al., 2016), autobiographical information visually presented (e.g., home town; Gray et al., 2004), participant’s national flag (Fan et al., 2011), and first person possessive pronouns (Shi et al., 2011; Zhou et al., 2010).

More recently, attentional biases for owned property have been identified, using a novel paradigm developed to explore early stage self-object processing while controlling for confounds such as familiarity, the label-shape matching task (Yankouskaya, Palmer, Stolte, Sui, & Humphreys, 2016). In the label-shape matching paradigm, a 2D shape (e.g. triangle, square, circle), is associated with a label (for example, you, friend, stranger). A matching task is performed, where the participant must indicate if a label-shape pair is congruent (matches the initial learned shape-label pairing), or incongruent (it has been reassigned, for example, self shape with friend label), with the initial allocations (Sui, He, & Humphreys, 2012). To observe whether attention is biased toward self-objects, participants performed an adapted version of the matching task with the shape appearing to the left or right of the visual field. Correct label-shape pairings were responded to by performing an anti-saccade (look away from the shape), and responses to mismatched pairings with saccades toward the shape. Relative to friend and stranger shapes, participants produced more errors when performing anti-saccades for self-owned pairings, suggesting that self 'owned' stimuli hold attention (Yanouskaya et al., 2016).

Label-shape associations appear to be a crude form of self-object association due to their arbitrary and temporary association. Therefore, it is possible to question their ecological relevance when specifically considering how object ownership, rather than self-relevant information in general, may influence attentional processes. However, once formed, the shape-label pairings are difficult to discard when reassigned in a second task (Wang, Humphreys, & Sui, 2016). This suggests the degree of association is less temporary than may be intuitively supposed.

In addition, attentional biases for self-associated objects do extend beyond geometric shapes to more ecologically valid objects. 'Owned' objects in the Cunningham shopping task (Cunningham et al., 2008) similarly influence such attentional processes. Replicating findings that other categories of self-relevant stimuli moderate the amplitude of the P300 ERP component, an index of attentional processing (see Gray et al., 2004), Turk et al. (2011) observed greater amplitude of the P300 component at the moment the object was flagged as self-owned (vs. experimenter's), during the task.

Complementing these findings, Truong et al. (2016), observed a tendency to report seeing a self-owned object (previously associated to the self in a learning phase) before the object belonging to the research assistant, when both were presented simultaneously (temporal order judgment task; TOJ). Such prior entry of one stimulus when two are presented simultaneously (and at varying onset asynchronies) is assumed to reflect attentional processes facilitating stimulus perception (for a review, see Spence & Parise 2010). The authors interpret this finding as illustrating an attentional set for 'own' biasing detection of self-owned belongings (Truong et al., 2016).

Perceptual advantages?

The findings reviewed so far indicate that, like other types of self-relevant stimuli, owned objects are prioritised during the allocation of attentional resources, and receive a mnemonic advantage, possibly because of greater attention allocation. However, objects associated with the self may also receive facilitated processing earlier in the processing stream, during stimulus categorisation.

For example, in the label-shape matching task it has been robustly observed that participants are faster to identify congruent matches for self-shapes (‘you / yourself’), than for a variety of other labels including: ‘friend’ ‘mother’, ‘stranger’ and ‘none’ (Sui et al., 2012; Sui & Humphreys, 2015a; Sui, Rothstein, & Humphreys, 2013; Schäfer, Wentura, & Frings, 2015). This *self-prioritization effect* remains when controlling for potential confounds such as word length, frequency, and is also present when using real names rather than abstract ‘you, friend, stranger’ tags (Sui et al., 2012). Taken together, these findings allude to self-relevant ‘objects’ exerting a prepotent effect on perceptual processing. Congruent with this explanation, responses to ‘self’ shapes, compared with non-self stimuli, are less sensitive to degradation of the stimulus (Sui et al., 2012), a manipulation assumed to influence early stages of visual processing (Mechelli, Humphreys, Mayall, Olson, & Price, 2000). In addition, akin to the effects of interference of a distractor stimulus with high perceptual salience (e.g., high contrast), when responding to a low salience target, self-shape distractors interfere with responses to other-shape targets, but not vice versa (Sui, Liu, Mevorach, & Humphreys, 2015), indicating that objects associated with the self, have greater salience during perceptual processing.

However, the cognitive stage at which such biases occur is disputed. Whether faster matching responses for self results from facilitated processing of stimulus characteristics, or represents response biases (a bias toward earlier response, based on less stimulus information), has recently been explored (Golubickis, Falben, Cunningham, & Macrae, in press). Prior to a categorisation task using objects (pens or pencils), participants were informed they owned all objects from one category (pens or pencils), while another individual (stranger, or friend), owned the other. Participants then categorised the objects, pressing one key for self-owned, and another for stranger/friend. Mirroring findings from the shape-label matching task (e.g. Sui et al., 2012), participants were faster to categorise self-owned objects, suggesting self-prioritisation bias is present during real object discrimination.

However, the data was subjected to hierarchical drift diffusion model analysis (HDDM; Wiecki, Sofer, & Frank, 2013), which separates processing effects (information uptake regarding the stimulus) from response biases (the point at which individuals have enough evidence to respond; White & Poldrack, 2014). HDDM identified this self-prioritisation effect as resulting from response bias, rather than enhanced information gathering (see also Macrae, Visokomogilski, Golubickis, Cunningham, & Sahraie, 2017). Therefore, it appears individuals may have different thresholds for the amount of perceptual information required to initiate self-owned responses, relative to other-owned rather than processing self-owned stimuli ‘faster’.

Neural mechanisms of self-object processing

Whether self-prioritisation effects reflect enhanced perceptual processing, or altered thresholds for response initiation, objects owned by the self, akin to other self-relevant stimuli, are preferentially treated at various levels of cognition. These findings raise questions concerning the neural basis of such biases, and whether they reflect a discrete network sensitive to ‘self’.

A neural region consistently implicated in the production of self-relevant biases is the medial prefrontal cortex (mPFC; for a meta-analysis of cortical midline structures recruited in self-referential processing, see Northoff et al., 2006; Northoff & Bermpohl, 2004). In addition to regions associated with memory and elaborative encoding, the mPFC is preferentially active during self-relevant evaluations in trait-evaluation tasks (Kelley et al., 2002), and similarly, in response to self-owned items in the shopping basket task (Turk et al., 2011). Furthermore, suggesting a causal role for the mPFC in self-memory biases, the magnitude of activation has been found to predict the subsequent recall of self-traits (Macrae, Moran, Heatherton, Banfield, & Kelley, 2004); and self-owned stimuli (Turk et al., 2011; see also Kim & Johnson, 2012).

Beyond self-owned objects eliciting mPFC activation at the point of forming self-object associations, it is also spontaneously activated when merely presented with a possession the participant had previously been tasked with imagining owning, and the magnitude of such activation predicted changes in object preference (mere ownership effect; Kim & Johnson, 2014). Therefore, there appears to be a key overlap in the way owned objects are processed, and how other self-relevant stimuli are treated. This lends further support to the theoretical notion that owned objects are treated as extensions of the self (Belk, 1988), and that self-object associations are virtually instantaneous (Turk et al., 2011; Kim & Johnson, 2012; LeBarr & Shedden, 2017).

Self shape-label biases also mediate activation of medial prefrontal regions (ventromedial prefrontal cortex; Sui et al., 2013). However, in addition, the left posterior, superior temporal sulcus (LpSTS), an area implicated in guiding attention in our social environment (e.g., Saxe & Kanwisher, 2003), is also recruited (Sui et al., 2013). Based on these findings, Humphreys and Sui (2016) formulated the SAN (Self-Attention Network), proposing that the vmPFC is sensitive to the presence of self-relevant stimuli, in turn activating the LpSTS, to prime orienting to self-owned items. Findings that self-biases in matching and memory are abolished in a patient with mPFC damage, while greater self-biases result from LpSTS lesions supports the functional connectivity of this network (Sui, Enock, Ralph, & Humphreys, 2015).

Is self always special?

It appears we possess a neural network instigated in processing ‘self’ stimuli and facilitating subsequent encoding (for suggestion that the function of SAN *is* to ensure self-relevant information is encoded, see Cunningham 2016). However, self-objects are not infallibly prioritised. In addition to the mPFC-LpSTS network that assists in sensitivity for self, an independent control network acts to suppress attention to self-stimuli when inappropriate. For example, a neural region recruited when visually salient distractors must be inhibited (the intra-parietal sulcus; Mevorach, Shalev, Allen, & Humphreys, 2009), is similarly active when ‘overriding’ a socially salient self-distractor, to respond to a low socially salient ‘other’ shape (Sui et al., 2015). Therefore, we do have some volition in suppressing attention to self when required.

Self-biases are also mediated by contextual demands. For example, in the label-shape matching task, participants were not sensitive to social saliency (a self distractor, considered ‘high salience’ interfering with an other-target), when the task required discrimination of the shape presented, rather than categorising whom the shape ‘belonged’ to (Liu & Sui, 2016; for contextual mediation when detecting location, see Stein, Siebold, & van Zoest, 2016). The presence of self-prioritisation in the shape-label matching paradigm is also influenced by top-down expectancies. For example, increasing stimulus probability of the ‘other’ pairings improves performance, relative to equal probability conditions. Although, it is important to note that a reduction in stimulus probability does not impact self-owned matches, as it does mother and stranger responses (Sui, Sun, Peng, & Humphreys, 2014). Therefore, self-relevant objects do not possess absolute salience.

Akin to explicit evaluative biases associated with ownership (Maddux et al., 2010), self-object processing biases are also mediated by sociocultural experiences that influence self-construal. As predicted by interdependent self-construal that emphasises interconnectedness with others (Markus & Kitayama, 1991), East Asian participants displayed greater recall for mother-owned objects, relative to self-owned, in the shopping task. This contrasted with Western participants, who displayed the normative self-referential effect (Sparks, Cunningham, & Kritikos, 2016), and was consistent with findings that Asian participants perform equally for traits encoded with relation to the self and mother (vs. stranger; e.g. Zhu & Zhang, 2002; Zhang et al., 2006). However, representation of the self on low level perceptual matching tasks is potentially malleable regardless of sociocultural experience; such biases extend to social groups individuals identify with, such as own and rival football teams (Moradi, Sui, Hewstone, & Humphreys, 2015). Performance in the standard shape-label paradigm also falls on a continuum, although self receives the greatest advantage, familiar others such as mother elicit faster response times compared with stranger labels (e.g., Sui et al., 2012).

Findings that perceptual matching enhancement extends beyond objects associated with self labels, and that stimuli associated with others do receive some degree of prioritised processing over stranger, may suggest self-processing is not special. Instead, self-biases may result from more general processes in response to other stimulus characteristics. For example, familiarity is one such general stimulus feature that could possibly account for the observed differences. However, given that low stimulus probability differentially affects response facilitation for matches for a highly familiar other compared with self-matches (Sui et al., 2014), it is unlikely that familiarity solely accounts for the prioritisation of self.

It is also plausible that self-prioritisation effects could be underpinned by the differential valence or reward value of self-stimuli relative to familiar other and stranger items (for valence, see Ma & Han, 2010; for reward, see Northoff & Hayes 2011). As previously discussed, we possess positive self-biases (Pelham et al., 2005), that extend to owned objects, increasing evaluations (e.g., Beggan, 1992; Nesselroade et al., 1999; Ye & Gawronski, 2016). Mirroring self-prioritisation effects and, therefore, situating valence as a possible mechanism, response times during categorisation of positive stimuli (for example, happy facial expressions, positive words, and other positive images), are faster than those for negative valence (for example, see Cunningham, Johnson, Gatenby, Gore, & Banaji, 2003; Lehr, Bergum, & Standing, 1966; Leppanen & Hietanen, 2004). Similarly, distractors previously associated with a high reward value have been found to capture attention, relative to low reward distractors (Anderson, Laurent, & Yanis, 2011; Anderson & Yantis, 2013). When directly comparing shape-label matching performance between shapes associated with differing reward value (£9, £3, £1), with self, friend, and stranger matching, high reward stimuli were also categorised faster than low-reward, akin to self-shape performance (Sui et al., 2012). However, the influence of reward value and self-relevance on stimulus processing does appear to differ under other task contexts, suggesting self-processing biases are not solely underpinned by the greater reward value of self-stimuli (see Sui, Yankouskaya, & Humphreys, 2015; Sui & Humphreys, 2015b; Sui & Humphreys, 2015c). When comparing self-relevance judgments with reward tasks (gambling; Enzi, de Greck, Prosch, Tempelmann, & Northoff, 2009), and viewing affective imagery (Phan et al., 2004), there is *some* overlap in neural regions associated with affect across task types. However, other neural regions were only active during self-tasks. Therefore, it is likely that self-object associations are at least partially underpinned by an affective or reward component, but the self-biases discussed do not *only* result from affective qualities.

Ownership beyond a vehicle for self-relevant biases

Despite self-relevant stimuli, including self-owned property, receiving processing advantages, the research discussed still indicates that such biases are flexible; we do not always prioritise self, insensitive to other cues. However, shapes matched to other, or property belonging to another, is often used as a comparative group of less importance, to illustrate superior performance for self. While tracking our own objects within the environment is important to protect our property, it is also necessary and advantageous that we quickly identify and remember whether objects are owned, and who owns them, to avoid potentially costly interactions. A study by DeScioli, Rosa, and Gutchess (2015) observed that recall for items was superior for object-person pairs (with the participant told that the individual owns the objects), compared with object-person ‘unrelated’ pairs. This suggests that alongside findings that we afford our own objects a memorial advantage, individuals also encode the ownership status of others’ property, compared with the recall of objects with no attributed owner, a condition not compared previously by Cunningham et al. (2008; 2012; 2013). Therefore, other-ownership cues possess, at least a recall advantage, relative to unowned items.

Other-ownership influences other cognitive processes. As we perceive objects, their ownership status is not only informative to the extent that it may be MINE, and therefore self-relevant, the concept of ‘mine’ or ‘yours’ is informative about what I am allowed to do with that object. When acting on objects, knowledge of ownership status may affect the visuomotor system by its contextually relevant nature of embodying rights to use, or not use. Embodied cognition offers a framework through which to understand how knowledge of ownership may influence the visuomotor system.

Embodiment

Embodied cognition is not one unified theory (see Wilson, 2002; Barsalou, 2008), but a position that, in its strongest form, posits the rejection of concepts as represented in an abstract manner, comprised of amodal symbols (e.g., Fodor, 1975). Instead, knowledge is considered as represented by, or at least, associated with, the sensorimotor states experienced during perception and action. For example, ‘chocolate’ is represented by modalities that process its taste, smell, visual features, and introspective experiences (such as pleasure or reward) while eating it. Later, when stumbling across chocolate in the kitchen cupboard (‘online’ cognition), or thinking about chocolate (‘offline’ cognition), the multimodal information associated with it is reactivated (simulated; Barsalou, 1999; 2008; Gallese & Lakoff, 2005; Garbarini & Adenzato, 2004; Simmons & Barsalou, 2003; Barsalou, Santos, Kyle, Simmons, & Wilson, 2008).

Due to the sheer volume of theory and investigative enquiry falling under the umbrella of embodied approaches to cognition, an exhaustive review is not tenable (for just two reviews, see Barsalou, 2008; Shapiro, 2010). For example, embodiment can also be extended to the processing of social actors, as we appear to simulate observed emotions and pain (Dimberg, Thunbergh, & Elmehed, 2000; Morrison, Lloyd, De Pellegrino, & Roberts, 2004), and other’s actions (e.g., Buccino et al., 2001), offering a mechanism for understanding others’ behaviour (see Grafton, 2009; Fadiga, Craighero, & Olivier, 2005; Cavallo, Becchio, Sartori, Bucchioni, & Castiello, 2012), and mental states (for reviews, see Gallese, 2003; Gallese, & Sinigaglia, 2011). In addition, it remains disputed whether concepts are truly *represented* by sensory and motor experiences, or merely related sensorimotor experiences are activated as *a result of* conceptual processing (disembodied theories; for discussion, see Mahon & Caramazza, 2008; Mahon, 2015).

Limited evidence relevant for understanding the elicitation of sensorimotor states during cognition can be found in the activation of motor regions associated with grasping (as if interacting with the object), during object observation, even in the absence of intention to act (Chao & Martin, 2000; Grafton, Fadiga, Arbib, & Rizzolatti, 1997; Grezes & Decety, 2002; Grezes, Tucker, Ellis, & Passingham, 2003; for a review, see Lewis, 2006). Similarly, motor regions are activated during the comprehension and production of action verbs (Hauk, Johnsrude, & Pulvermuller, 2004; Buccino et al., 2005). Activation of associated sensorimotor states extends beyond motor activity to other modalities. For example, neural regions associated with gustation are activated when viewing food (Simmons, Martin, & Barsalou, 2005), and areas linked to smell perception are recruited during the comprehension of odour-related words (for example, 'cinnamon'; Gonzalez et al., 2006). Affective reactions, such as increased galvanic skin response, are activated during comprehension of negative emotive words (Harris, Aycicegi, Berko, & Gleason, 2003), and recruitment of the muscles invoked during smiling are active during comprehension of verbs referring to facial expressions (Foroni & Semin, 2009). Even abstract concepts that cannot be directly perceived, so seemingly cannot be rooted in perceptual experiences, appear to be associated with sensorimotor experiences of more concrete concepts. For example, morality appears to be linked to cleanliness, evidenced by hand washing reducing the extent to which immoral actions were perceived as wrong (Schnall, Benton, & Harvey, 2008), and an increase in desire for cleaning products after performing a moral transgression (Lee & Schwarz, 2010).

Activation of such states during stimulus processing subsequently alters performance. For example, when responding to a graspable object, action performance is facilitated, providing the action executed is congruent with the motor activity 'primed' during perception (Tucker & Ellis, 1998; Tucker & Ellis, 2004). Similarly, when perceiving emotional facial expressions, performance is impaired if the use of the muscles associated with the performance of facial expressions is prevented (for example, by holding a pen between the teeth; Niedenthal, Brauer, Halberstadt, & Innes-Ker, 2001; Oberman, Winkielman, & Ramachandran, 2007). However, the connection between sensorimotor experience and cognition is bi-directional. For example, alongside the activation of affective bodily states when comprehending emotive stimuli, inducing bodily states associated with affect, such as nodding the head (Wells & Petty, 1980), and engaging the muscles recruited in smiling (Strack, Martin, & Stepper, 1988), induces positive affective evaluations in individuals.

Despite criticisms levied at embodied approaches, there is substantial evidence that associated sensorimotor states are, at least, experienced during stimulus perception and conceptual thought, and vice versa when inducing states. However, as the potential states associated with a stimulus or concept are so vast; some proponents of embodied cognition also emphasise the role of environmental context as guiding which elements become active (e.g., Yeh & Barsalou, 2006). To extend the previous example, chocolate may be experienced as less delicious in a situation that signals health (for example, a gym), compared with indulgence (a coffee shop; Roefs et al., 2006). Contextual effects extend beyond evaluations; individuals are more accurate at identifying objects when they appear in coherent scenes (a chair in a living room), than scrambled displays, suggesting that the scene activated related concepts, facilitating response (e.g., Biederman, 1972). In addition, despite experiencing the same emotional response to threat (fear) in social contexts, and those indicating physical danger (the presence of a snake), different neural regions are recruited in preparation for response depending on whether the context is a social or physical threat. Networks involved in thinking about others (mentalising), are activated in social contexts, while regions associated with action planning are recruited during physical danger scenarios (Wilson-Mendenhall, Feldman Barrett, & Barsalou, 2013). Therefore, contextual cues also appear to pose importance in guiding cognition.

Embodied ownership

Ownership as a concept, ultimately, rests on the acceptability to interact with objects (Snare, 1972). Therefore, ownership may be embodied; that is, characterised by associated motor states, influencing subsequent action execution. A recent finding that memory for self-owned objects was further improved when the objects were brought toward the torso during categorisation (vs. moved away from the body) is suggestive of the association of bodily (proximity) and motor states (approach; Truong, Chapman, Chisholm, Enns, & Handy, 2016) with ownership. In a bi-directional fashion, object ownership shapes movement trajectories; with self-owned coffee mugs brought closer toward the body during lifting (Constable et al., 2011).

However, knowledge of other-ownership may also mediate motoric responses. We are motivated to maintain good social relations, as social rejection hurts akin to physical pain (e.g., Eisenberger & Liberman, 2004; Kross, Berman, Mischel, Smith, & Wager, 2011). To achieve this, we naturally engage in facilitatory behaviour, such as automatic mimicry of others, that increases other's ratings of the mimicker's likeability (Chartrand & Bargh, 1999; for trustworthiness, see Maddux, Mullen, & Galinsky, 2008). We do this increasingly in situations where we are excluded (Lakin, Chartrand, & Bargh, 1999). Given that we understand from an early age that inappropriate interaction with other's things can result in negative social interactions (Pewsowski & Friedman, 2016), to maintain good interpersonal relations and avoid the discomfort of social confrontation, we must remain sensitive to other's possessions during our interactions with the environment.

Constable et al. (2011), provide evidence to support this notion. In a stimulus-response compatibility task, participants responded to the colour of a mug handle, by performing left and right key presses. The mugs, decorated by participants prior to the study, belonging to the participant, the experimenter, another participant, and a plain, unowned mug, were displayed with the handle oriented to the left or right. In accordance with typical stimulus-response compatibility mappings (for example, see Simon, 1969; for a review, see Hommel, 2000), participants were faster to respond to their own mug, a mug belonging to another, and the unowned mug, if the handle orientation matched the response side required, compared with incompatible responses. However, crucial for our understanding of whether other-ownership cues mediate action, this typical S-R effect was abolished for the mug belonging to the experimenter. This finding is suggestive of sensitivity to ownership within the action system, as facilitation for spatially matched responses (and impaired performance for mismatched executions), is assumed to reflect activation of the response produced by the spatial dimension of the stimulus (Hommel, 2000). Neuroimaging evidence also alludes to a lack of affordances for other-owned property, with activation of action-related neural regions responsive when viewing manipulable objects only during the viewing of self-owned objects (relative to other-owned), in the Cunningham shopping task (Turk et al., 2011).

Alongside affecting response time, reticence to interact with another's property can be observed in subtle changes to movement kinematics. Constable et al. (2011) observed that participants reached greater peak acceleration when lifting a mug they owned, compared with lifting a mug belonging to the another (experimenter). As discussed, the self-owned mug also drifted closer toward the participant's body during the lift; compared with an unowned mug. However, importantly, the other owned (experimenter's) mug was held furthest away from the torso. These findings suggest we restrain our actions when interacting with another's property, and the decreased acceleration may reflect taking extra care with another's mug.

Further research has replicated this effect (Constable, Kritikos, Lipp, & Bayliss, 2014), but also observed that, in line with a situated view of cognition, this ownership effect is mediated by social context. When the owner of the mug was known, but not present, during action performance (the other-owned mug belongs to a confederate, rather than the experimenter), the acceleration effect observed when the owner was in the room was abolished (Constable et al., 2014). Therefore, taking Constable et al. (2011) and Constable et al.'s (2014) findings together, we can start to build an understanding of other-ownership, which suggests that we do not cognitively 'treat' and respond to all other-owned property in the same fashion. From a young age we assume manmade artifacts are likely to be owned (vs. natural artifacts; Neary, Van de Vondervoort, 2012; Van de Vondervoort & Friedman, 2015). Given this, we may anticipate that we cognitively 'treat' all manmade artifacts not owned by the self as 'other-owned', processing and responding to them in an identical manner, regardless of whether we know an object is owned by someone not individually identified, the owner's identity is known, or the ownership status of the object is unspecified. However, Constable et al.'s (2011; 2014) findings indicate that individuals demonstrate sensitivity to whether the owner is known (experimenter) or unknown, and also whether the owner is present, during other's motoric interactions with their property.

More recently, Constable and colleagues (2016) have extended observations of the modulation of motor behaviour as a function of ownership to another action context; joint action execution. They observed that, when passing a mug to a partner for them to use it, the handle of the partner's mug was oriented more greatly towards the receiver (partner), compared with the mug belonging to the participant. However, again illustrating that even subtle contextual factors shape the influence of ownership on performance, this effect did not occur when the receiver was *not* going to act upon the object. Therefore, knowledge of object ownership does appear to shape action performance. However, these effects extend beyond the facilitation of action for self-owned property that we may expect, given the adaptive value of self-ownership biases across cognitive processes, and the likelihood that self-owned property is associated with motor states. Combined response time and kinematic evidence also alludes to a reticence to interact with other's belongings, but only if the owner is known and present.

Thesis purposes

Although historically slow to emerge, there is now a substantial amount of evidence indicating that self-associated objects are privy to facilitated cognitive processing: demonstrating a recall advantage for self-owned objects (relative to other-owned; e.g., Cunningham et al., 2008), attentional biases for the selection of self-owned property (e.g., Yanouskaya et al., 2016; Turk et al., 2011), and facilitated stimulus discrimination (e.g., Sui et al., 2012). Despite this increase in interest in ownership and cognition, and evidence that while self-biases are prepotent, they are nevertheless flexible, substantially less research has investigated how knowledge of other-ownership shapes cognition, and subsequent motoric responses. Most frequently, self-ownership has been situated as another stimulus 'category' through which to investigate general self-relevant cognition, with other-ownership acting as a social, but less salient, comparison group. The adaptive nature of self-biases is undeniable, facilitating protection of our property from appropriation by others, and focusing processing resources on objects that are more likely to be acted upon. However, developmental work illustrating that understandings of ownership (e.g., Neary & Friedman, 2014; Rossano et al., 2011), and the ability to infer other-ownership (Friedman & Neary, 2008b; Friedman et al., 2013), develops early in childhood, attests to the importance of sensitivity to property belonging to others. However, consideration of the processing, and effects, of other-ownership remains limited to all but a few studies.

An embodied approach to cognition would suggest that the effects of, both self-ownership, and other-ownership, may be most observable in the sensorimotor processes that sociocultural norms, and everyday experiences, of ownership govern; action production. Indeed, initial evidence from Constable et al. (2011; 2014; 2016), indicates that motor responses during object-directed action are shaped by ownership status, including effects of other-ownership status that suggests a sensitivity to not only 'other-ownership', but who owns the property and the presence of the other-owner during action performance; shifting focus beyond the influence of self-ownership. Therefore, the primary aim of this thesis is to further develop understanding of the influence of ownership, especially other-ownership, on motor behaviour in two central ways.

The first aim of the thesis is to extend findings concerning embodied ownership effects during object-directed action by investigating whether ownership produces affective compatibility effects: embodied motoric responses to positive and negative affect (discussed in more detail in Chapter 2; for example, Chen & Bargh, 1999). Given the positive biases we exhibit for the self, that extend to our own property, self-ownership may be, in part, linked to positive affective states, and therefore facilitate approach motions. In addition, other-ownership may signal negative social consequences of interaction, facilitating avoidance movements.

Findings from movement kinematics designs, that self-owned mugs are drawn closer to the body, compared with that belonging to another, and positioning of the experimenter's furthest from the torso indirectly alludes to facilitated approach behaviour for self-owned property and other-ownership eliciting avoidance responses (Constable et al., 2011; Constable et al., 2014). Therefore, to more directly assess the tendency to approach and avoid as a function of ownership status, in Chapter 2, Experiments 1 to 3 adopted a computerised approach-avoidance task. Participants produced approach and avoidance movements while categorising self-owned mugs and property belonging to another to compare response time differences in approach and avoidance movements for objects of different ownership status.

Attempting to add further evidence to the prior literature (Constable et al., 2011; 2014), that provides initial findings suggestive of motoric responses being mediated by the level of other-ownership (with objects owned by a known individual (experimenter) being subjected to the greatest degree of 'avoidance' behaviour, vs. an object owned by an unknown individual, and an unowned item); we also included an object owned by the experimenter, an unknown other, and an unowned object. We anticipated that we would observe a similar pattern of effects, with the level of other-ownership producing differing degrees of avoidance facilitation; namely, observing the greatest degree of avoidance facilitation for the experimenter's object (relative to approach for this object, producing a significant difference), followed by the mug belonging to an unknown other eliciting faster avoidance responses (relative to approach). We anticipated a significant difference in avoidance (vs. approach) response times would be absent for the unowned object.

Chapter 3 extends the investigation of approach and avoidance behaviour as a function of ownership status, exploring whether more informative findings concerning compatibility effects can be better elucidated using measures with greater sensitivity, compared with response time, especially as ownership is a contextually sensitive and subtle variable. Participants performed approach and avoidance movements by physically moving the self-owned or experimenter-owned mug toward or away from the torso while the spatial and temporal parameters of their movements were recorded using motion-tracking technology.

The secondary aim of this thesis is to investigate the influence of ownership status in a motoric context that has yet to be considered, and is arguably a context in which other-ownership may possess the greatest degree of salience: obstacle avoidance. All research to date, including Experiments 1 to 4, has explored action performance when interacting with (for example, lifting or moving), objects of differing ownership status (Constable et al., 2011; 2014; 2016). However, it is equally interesting to consider how we execute movements in the presence of obstacles belonging to the self, or other. We frequently navigate space inhabited by non-target objects, and we are incredibly proficient in doing so without colliding with obstacles.

Discussed in more detail in Chapter 5, to achieve this, we increase movement time, and alter reach trajectories to optimise the passing distance of our acting limbs from the obstacles (Chapman & Goodale, 2008). Traditionally, it was theorised that features related to the identity of the obstacle (for example, whether it is fragile), did not mediate the temporal and spatial parameters of avoidance movements (Goodale & Milner, 1992; Milner & Goodale, 2008). However, recent evidence suggests that identity-related features do influence avoidance behaviour, with objects that pose greater consequences if collided with eliciting an enhanced avoidance response (De Haan, Van der Stigchel, Nijnens, & Dijkerman, 2014; Kangur, Billino, & Hesse, 2017). Ownership status is another higher order feature of objects determining the cost of colliding with an object (in terms of maintaining good social relationships with others). As we navigate the cluttered table to retrieve the biscuits, knocking over the coffee mug belonging to a colleague is likely to have greater implications than ‘bumping into’ our own mug. Thus, Experiments 5 to 7 in Chapter 4 aimed to elucidate whether temporal and spatial parameters of reaching movements differed in the presence of obstacles of differing ownership status, either owned by the experimenter, or belonging to the participant.

Chapter 2. Interacting with ownership: Affective compatibility

We act upon an environment of stimuli associated with positive and negative affect; we are inclined to reach and grasp some objects, while others may elicit repulsion and cause us to avoid them. The ownership status of objects (mine or yours) may contribute to an object's valence and mediate our subsequent response tendency.

Affective compatibility effects

It has long been proposed that we possess an automatic affect-based processing system. This system is assumed to serve survival, allowing us to respond quickly to valenced stimuli with appropriate responses; such as avoiding dangerous animals and approaching high-value resources (LeDoux, 1996). This network is postulated to be distinct from other more lengthy cognitive processing mechanisms (LeDoux 1996; Zajonc, 1980). However, it is disputed whether affect processing is fundamentally different from the processing of other stimulus features, such as shape (for a review, see Eder, Hommel & Houwer, 2007). Its proposed automaticity is also challenged by findings that affect-related information does not alter response times when irrelevant to the goal of a task (only when an evaluative judgment relating to valence is made), suggesting that the processing of valence is subject to cognitive resources and control (Klauer & Musch, 2002). However, Rinck and Becker (2007) did identify an affective compatibility effect for angry faces, with participants faster to avoid than approach (relative to neutral faces), when the task required participants to categorise the stimuli by their type (face or puzzle), rather than respond to the affective component. Therefore, it is unclear whether affect processing occurs when not task-relevant.

Regardless of how affect processing is conceptualised, as relying on a distinct system or recruiting similar cognitive mechanisms as non-affective information; there is a body of evidence indicating that motor output is influenced by our evaluation of objects as good or bad. For example, Chen and Bargh (1999) observed that individuals were faster to categorise positive and negative words if the movement required was congruent with word valence. Participants were faster to respond to positive words with lever pulls (arm flexion, an approach response of pulling the stimulus closer the self) compared with pushing the lever away (arm extension, classified as avoidance by pushing the item away). The opposite effect was found when responding to negative words; with participants faster to push the lever (avoid) than pull (approach). Pictorial stimuli elicit the same pattern of results (Rotteveel & Phaf, 2004), and a recent meta-analysis of 68 approach-avoidance studies identified a small but significant affective compatibility (approach-avoidance) effect (Laham, Kashima, Dix & Wheeler, 2015).

In a bi-directional fashion, motor responses shape the evaluation of stimuli. Cacioppo, Priester and Berntson (1993) observed that objects were evaluated more favourably when the arm was placed in a position associated with approach (arm flexion), compared with evaluations after arm positioning in an avoidance position (arm extension). Such findings allude to the embodied nature of affective compatibility effects; with representations across modalities, such as action, activated by affective evaluation, and in turn, motor behavior associated with positive and negative affect also affecting concurrent stimulus evaluations (Niedenthal, Barsalou, Winkielman, Krauth-Gruber & Ric, 2005).

However, we do not passively respond to stimuli ‘pre-programmed’ with affective features. Albeit, some stimuli may elicit similar evaluations across individuals, stimulus valence varies by individual. Rinck and Becker (2007) found that spider phobics responded more quickly than control participants when pushing a joystick (avoid) in response to spider images compared with pulling (approach). Individual differences have also been observed between smokers and non-smokers when categorizing smoking paraphernalia (Mogg, Bradley, Field & De Houwer, 2003).

Contextual mediators

Traditionally it has been assumed that stimulus affect activates specific muscle patterns; with arm flexion movements associated with approach, and avoidance with arm extension (for example, see Cacioppo et al., 1993; Centerbar & Clore, 2006; Rotteveel & Phaf, 2004). However, arm flexion and extension are ambiguous. Both movements produce differing consequences. Arm flexion can bring an object closer to the body, but also represents a withdrawal of the hand from an object. Conversely, arm extension is recruited to we reach for something we like, but also when pushing objects away.

Seibt, Neumann, Nussinson and Strack (2007) varied explicit task instruction while performing a word categorization task, demonstrating that approach and avoidance movements are defined and facilitated by their consequences; rather than tied to specific motor responses. One group was instructed to imagine pulling an item toward the self, when pulling the joystick (flexion), and pushing an object away from the self (joystick push - extension). In the other condition, the instructions given prior to the task were verbally framed with reference to the object; reaching toward the object with joystick push movements (extension), and away from objects with the pulling movement (flexion). In line with Chen and Bargh (1999), participants in the self-reference condition were quicker to categorise positive words with ‘pull’, and negative with ‘push’, movements. However, this pattern was reversed in the object-reference condition, with faster responses to positive words with ‘push’ movements and negative words using ‘pull’ motions. Even adaption of the hand posture (open vs. closed grasp) during performance of arm flexion and extension movements can lead to a ‘remapping’ of compatibility effects (see Freina, Baroni, Borghi & Nicoletti, 2009).

Offering further support to the notion that actions are defined as approaching and avoiding as a result of their perceived consequences; affective compatibility effects can also be obtained in tasks recruiting ‘neutral’ movements such as button presses, that do not recruit arm flexion or extension but initiate the movement of the stimulus toward or away from the participant (Dantzig, Pecher & Zwaan, 2008). Bamford and Ward (2008) also observed a typical affective compatibility effect (faster to touch positive and avoid unpleasant stimuli) using a novel adaptation of an Approach-Avoidance Task recruiting interaction with a touchscreen monitor. Participants were required to produce only extension arm movements, but respond by touching an image (touch object; approach), or touching a ‘neutral’ stimulus (not touch target object; avoid) presented on the opposite side of the screen. Therefore, rather than affect recruiting specific motor patterns; movements appear to be facilitated on the basis of their consequences.

Ownership and motor effects

There is increasing evidence that the ownership status of objects (mine or yours) affects motor output. Constable et al. (2011) found that participants restrained their actions when interacting with another’s property, indexed via reduced peak acceleration when lifting a mug belonging to the Experimenter compared with their own mug. The self-owned mug also drifted closer toward the participant’s body during the lift; compared with the unowned and experimenter’s mug (see also, Constable et al., 2014). In addition to differences in ownership status mediating the manipulation of objects; more direct reaching paths are taken when reaching to grasp a card displaying a shape ‘owned’ by the self, compared with the experimenter (participants were told they owned a 2D shape - oval or rectangle, prior to the task; Sparks et al., 2016). Both sets of authors suggest that the trajectory effects observed in response to self-owned objects may reflect facilitation of an approach response; potentially occurring as an embodied response to the differential valence of self-owned and other-owned property.

As discussed in Chapter 1, self-associated stimuli, such as objects we own, are afforded perceptual advantages mirroring those observed for stimuli associated with reward (Sui, et al., 2012). The effects of reward and self-relevance do diverge under other task contexts (Sui, Yankouskaya & Humphreys, 2015; Sui & Humphreys, 2015b; Sui & Humphreys, 2015c). However, there is some neural overlap for reward and self-relevance (Enzi et al., 2009). We also prefer (Beggan, 1992; Huang, Wang & Shi, 2009), and financially value more highly (Morewedge et al., 2009; Kahneman et al., 1990; Kahneman & Tversky, 1984); objects we own, compared with identical objects owned by others and those with no owner. Therefore, although it is unlikely that self-processing biases in general are a result of only stimulus reward value; there is likely an underlying reward-based component of ownership. It is therefore reasonable to assume that the act of owning potentially endows objects with positive valence, which may produce affective compatibility responses

A recent study considered the effects of performing approach and avoidance actions on previously identified memory biases for self-owned objects (for example, see Cunningham et al., 2008). Moving owned objects (vs other-owned) toward the body enhanced subsequent object recall, compared with the recall of 'own' objects pushed away, and 'other' objects moved toward or away from the self (Truong, Chapman, Chisholm, Enns, & Handy, 2016). Time taken to initiate or execute the movements (reflective of facilitated motor processes) did not depend on the congruency of the movement performed (congruent: own pulled toward self; incongruent: own pushed away from self and vice versa for owned by another). Therefore, although memory was improved when action and ownership were congruent; the execution of congruent actions was not facilitated, as we would predict. However, the actions were performed at the time of encoding the object as 'owned'. The discussed motor effects that may allude to facilitated approach response for owned objects (Constable et al., 2011; Sparks et al., 2016), utilised stimuli with ownership assigned prior to task completion. Therefore, affective associations that we propose may facilitate congruent movement performance may have yet to be formed.

The current research

Prior findings allude to the possible facilitation of approach movements for self-owned objects (Constable et al., 2011; Sparks et al., 2016), but no research to date has directly investigated the influence of ownership status on approach and avoidance movement performance with objects already owned by the participant using an Approach-Avoidance paradigm. Participants and the experimenter decorated coffee mugs in small groups and took them home to use, before returning to the laboratory to complete an adapted touchscreen version of an Approach-Avoidance task (Bamford & Ward, 2008).

Participants viewed images of their own, the experimenter's, another participant's and a plain mug on a grey square background; accompanied by a plain square on the opposite side of the screen. Participants explicitly categorised the mug as 'mine' or 'not mine', and also performed blocks responding to a feature of the stimulus image irrelevant to ownership. Participants produced approach (touch the mug) and avoid (touch square) movements to categorise the stimulus displayed.

We predicted that when ownership was task-relevant (approaching or avoiding on the basis of ownership) approach movements (relative to avoidance) would be facilitated for self-owned objects; as approach responses are congruent with the positive affect self-ownership likely invokes. Whether other-owned objects possess negative valence and may facilitate avoidance movements is less clear. The positioning of the experimenter's property furthest from the body during lifting (Constable et al., 2011; Constable et al., 2014), resulted in the tentative prediction that other-owned objects would invoke faster avoidance (vs. approach) responses. However, we anticipated that there would be no difference between time taken to avoid or approach the plain, undecorated mug; which signified no owner due to a lack of personalisation.

Some argue that we possess a dynamic self-memory system, designed to serve self-goals (such as identity stability) and ensure information relevant to these current goals is preferentially accessed (see Conway, 2005). Therefore, the detection of self-cues may be a perpetual goal, regardless of their task-relevance. However, akin to evidence that affective stimuli may not be processed 'automatically', when the affective component is not task-relevant (see Klauer & Musch, 2002), some initial findings suggest that the perceptual advantages afforded to self-stimuli do *not* occur in contexts where individuals are not performing judgments about whether they are associated with self or other (see Liu & Sui, 2016).

To explore whether any compatibility effects elicited for self-owned property would also occur in task-irrelevant contexts, in addition to the task recruiting an ownership judgement (mine or yours), we included a task where object ownership status was not relevant to the judgment performed.

Experiment 1

Method

Participants

Forty undergraduate students from the University of East Anglia, naïve to the purpose of the study, participated in exchange for financial gratuity. However, due to technical failure, only data from 37 (27 female; $M = 20.57$ years, $SD = 4.63$) participants is reported. All reported having normal or corrected-to-normal vision, and were right-handed. The University of East Anglia's School of Psychology Ethics Committee approved this study. Informed consent was obtained for both participation, and the use of a photograph of their mug in the experiment.

Stimuli and Apparatus

Stimuli. Prior to the experimental task ($M = 9.86$, $SD = 4.93$ days), both the experimenter and the participants decorated white, ceramic coffee mugs with a design of their choosing. The mugs were photographed on a plain black background, with the handle of the mug oriented 90^o to the right, compatible with the right-handedness of all participants.

The images of the mugs were prepared using Adobe Photoshop Elements 11 (Adobe Systems Inc., 2012); the background was removed, and the mugs resized (161.50 x 162 px). Two versions of the mug images were produced; with each mug placed on a square grey background (320 x 320 px), one with an orange and one with a purple border (30 px width). Once photographed, the participants took the mugs home to use ($M = 1.35$, $SD = 2.46$ uses).

Approach-Avoidance Task. The task was created and presented using E-Prime 2.0 (Psychology Software Tools Inc., 2012). A version was produced for each participant, featuring their own mug, the experimenter's, a mug belonging to an unknown other participant and an undecorated mug.

The task consisted of four blocks (two task-relevant, two task-irrelevant), containing 160 trials per block, and four practice trials. In one ownership as task-relevant block, the participant was required to touch the image of the mug if it belonged to them, and touch the plain placeholder if it was not theirs. In an ownership as task-irrelevant block the participant was required to tough the image with a purple border, this could be either the placeholder or the mug. Task instructions were reversed for the remaining block. Per block, each mug (own, experimenter's, unknown other and unowned) was presented 40 times, appearing in the left and right position, with an orange or purple border, an equal number of times. Ownership status, position and border colour was randomised across the block. Block order (A1A2B1B2) was counterbalanced across participants. However, participants always completed both task-relevant and both task-irrelevant blocks in succession.

Other materials. The approach-avoidance task was presented on a Dell personal computer with Logitech speakers and an ELO 1900L, 19" colour touchscreen monitor, with a resolution of 1280 x 768 with a 60-Hz refresh. Plain white ceramic mugs (9.3 cm tall, with a 8.7 cm diameter), and specialist porcelain paint (blue, green, red, yellow, pink and black) and brushes were used to decorate the mugs.

Design

The study adopted a 2 × 2 × 4 within-subjects design, manipulating task type, action and ownership status. Task type had two levels (ownership task-relevant, ownership task-irrelevant). Participants completed two blocks of the task-relevant task, where they performed a mine / not mine categorisation, and responded by touching the image of the mug, or the grey placeholder, depending on block instruction.

In the task-irrelevant block; participants touched the image with the orange border (either placeholder or the mug), or that with the purple border, requiring no evaluation of the ownership of the mug. Action consisted of two levels; with participants performing approach (touch the image of the mug) or avoidance (touch the placeholder without the mug present) movements. Four types of mug were presented: Experimenter's, own (participant's), belonging to an unknown other and no owner (a plain, undecorated mug).

The dependent variable was response time recorded in milliseconds (ms), the time taken to lift the space bar after an auditory go signal until the index finger contacted the monitor.

Procedure

Mug decorating. Participants initially attended one of two 60 minute group painting sessions. During these sessions the researcher also decorated a mug, an image of which (one of two mugs, depending on session attendance) appeared in the experimental task. Once photographed, the participants were asked to use their mug, as it was theirs to keep, but bring it with them upon returning to the laboratory for the experiment.

Task. Upon arriving for the experiment, the participant witnessed the researcher interacting with their mug in a naturalistic manner. Participants were seated at the computer in a moderately lit room, approximately 45-50 cm from the monitor, with the index finger of their dominant hand resting on the spacebar (placed 20 cm from the edge of the table). The researcher was present, seated unobtrusively, during task completion. Participants were informed that they were going to view a series of mugs, on either the left or right of the screen (on the adjacent side, a grey square without a mug would be present); and perform a series of judgments (such as whether the mug was theirs, or not theirs), responding by pressing different locations on the monitor.

Participants were informed of changes to task instructions (the commencement of a new block) via the monitor. Each trial was user initiated by pressing and holding the spacebar, proceeded by a fixation cross (500 ms), followed by the stimuli. 300 ms after the stimuli appeared, a tone sounded signaling response. The stimuli remained present until response (see Figure 1).

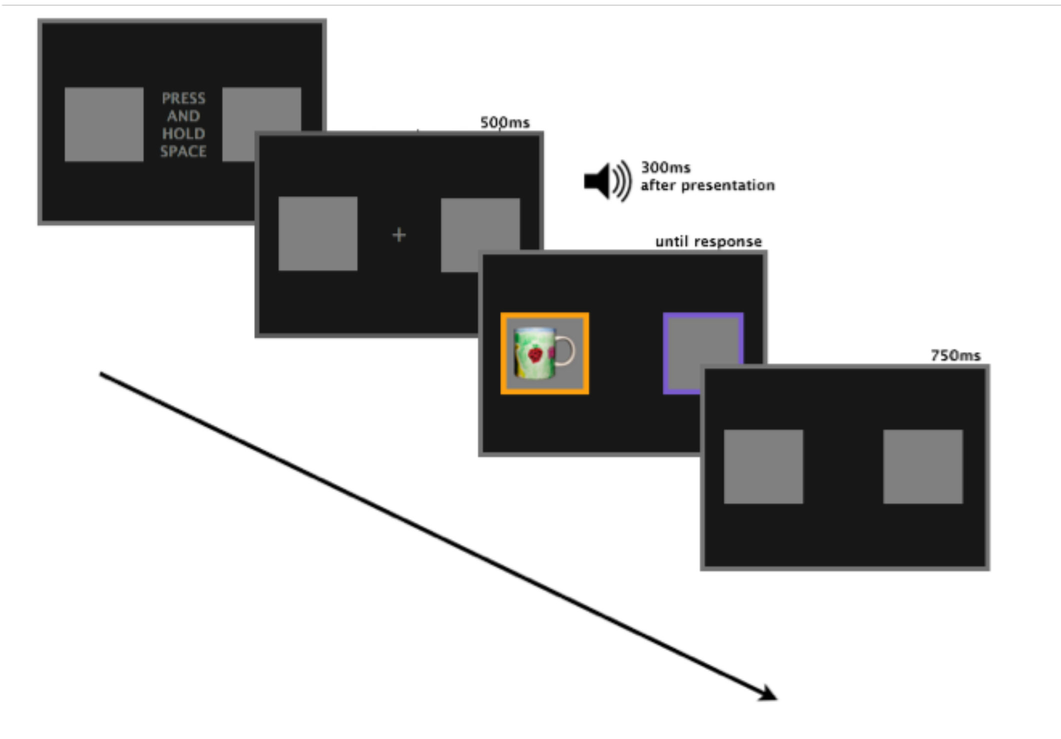

Figure 1. The time course of a trial for Experiment 1 (not to scale).

Participants responded by lifting the spacebar and using the index finger of the same hand to touch the screen, as quickly and accurately as possible. Once the participant had executed response, a blank inter-trial screen was presented for 750 ms, before the prompt to initiate the next trial. Grey placeholders remained present in the locations of the images throughout the trial procedure (both before and after stimuli onset).

If participants responded before the onset of the tone, they had to repress the spacebar and respond once the tone had sounded. Such trials were later eliminated from analysis. If the participant repeatedly responded before the onset of the tone, they were verbally informed not to do so. The task took approximately 30 minutes to complete.

Results & Discussion

Response times were averaged for per participant for each condition. Trials with errors (0.3%), and trials where participants responded before the tone (3.11%) were removed. One participant performing with an error rate above 15% within a single level of the ownership factor (due to limiting the number of trials per condition to compare to performance in the other levels, and being indicative of not attending to the task instructions); and another who responded before the tone on more than 15% of trials, were excluded from the analysis. Initial cut-off values of < 300 ms and > 3000 ms were used to exclude unrealistic response times (0.8%).

A 2 × 2 × 4 repeated measures ANOVA was conducted on the within-subjects variables of task type (ownership relevance), action (approach and avoid), and ownership status (own, experimenter's, unknown other's and unowned). Where sphericity assumptions were violated, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. Planned comparisons were not corrected, post-hoc tests were corrected using the Holm-Bonferroni sequential method and significant values were set at $p < 0.05$ (two-tailed).

The 3-way ANOVA identified a significant main effect of task [$F(1, 34) = 5.32$, $p = .027$, $np^2 = .135$]; with participants slower to respond to stimuli in the task-relevant judgment blocks (767 ms), compared with task-irrelevant (732 ms). There was no significant main effect of action [$F(1, 34) < 1$], ownership status [$F(2.22, 75.63) < 2$], task × action [$F(1,34) < 2$], and task × ownership status, $F(1.95,66.18) < 2$.

Most relevant for our predictions, the action × ownership status interaction was significant [$F(1.75, 59.45) = 11.71$, $p < .001$, $np^2 = .256$]. However, this was subordinate to the significant three-way task × action × ownership status interaction, $F(1.37, 46.64) = 18.44$, $p = .0111$, $np^2 = .352$. Therefore, two 2-way ANOVAs (ownership status × action) were conducted for the ownership task-relevant and task-irrelevant block separately.

Ownership as task-relevant

When exploring response time for the task-relevant blocks, there was no significant main effect of action [$F(1, 34) < 2$] or ownership status [$F(2.40, 81.52) = 2.29$, $p = .098$, $np^2 = .062$]. However, critical for our predictions, there was a significant two-way action × ownership status interaction, $F(1.38, 46.85) = 18.80$, $p < .001$, $np^2 = .356$ (see Figure 2).

Planned comparisons revealed that, as predicted, participants were significantly faster to approach (vs. avoid) their own mug, $t(34) = -5.85$, $p < .001$. This finding is consistent with previous studies that provide indirect evidence of facilitated approach for own property (Constable et al., 2011; 2014; Sparks et al., 2016). Facilitated avoidance for property owned by others was observed, with participants faster to avoid, compared with approach, the mug belonging to an unknown other, $t(34) = 3.41$, $p = .002$ (two-tailed). There was a clear trend toward faster avoidance for experimenter's, but this narrowly failed to reach significance, $t(34) = 1.89$, $p = .068$ (two-tailed). Contrary to our assumption that the plain, undecorated mug would likely possess neutral affective value and therefore no difference in approach or avoidance response time would be observed; participants were significantly slower to approach, compared with avoid, the unowned object, $t(34) = 3.05$, $p = .004$ (see Figure 2).

To further unpack the nature of the affective compatibility effects, the effect of ownership within each action was also subject to analysis. In line with facilitated approach for self-owned, participants were faster to approach self-owned than all levels of other-owned (all comparisons $p < .009$, see Appendix B), and participants were significantly faster to avoid all levels of other-owned, relative to avoiding self-owned (all comparisons $p < .001$).

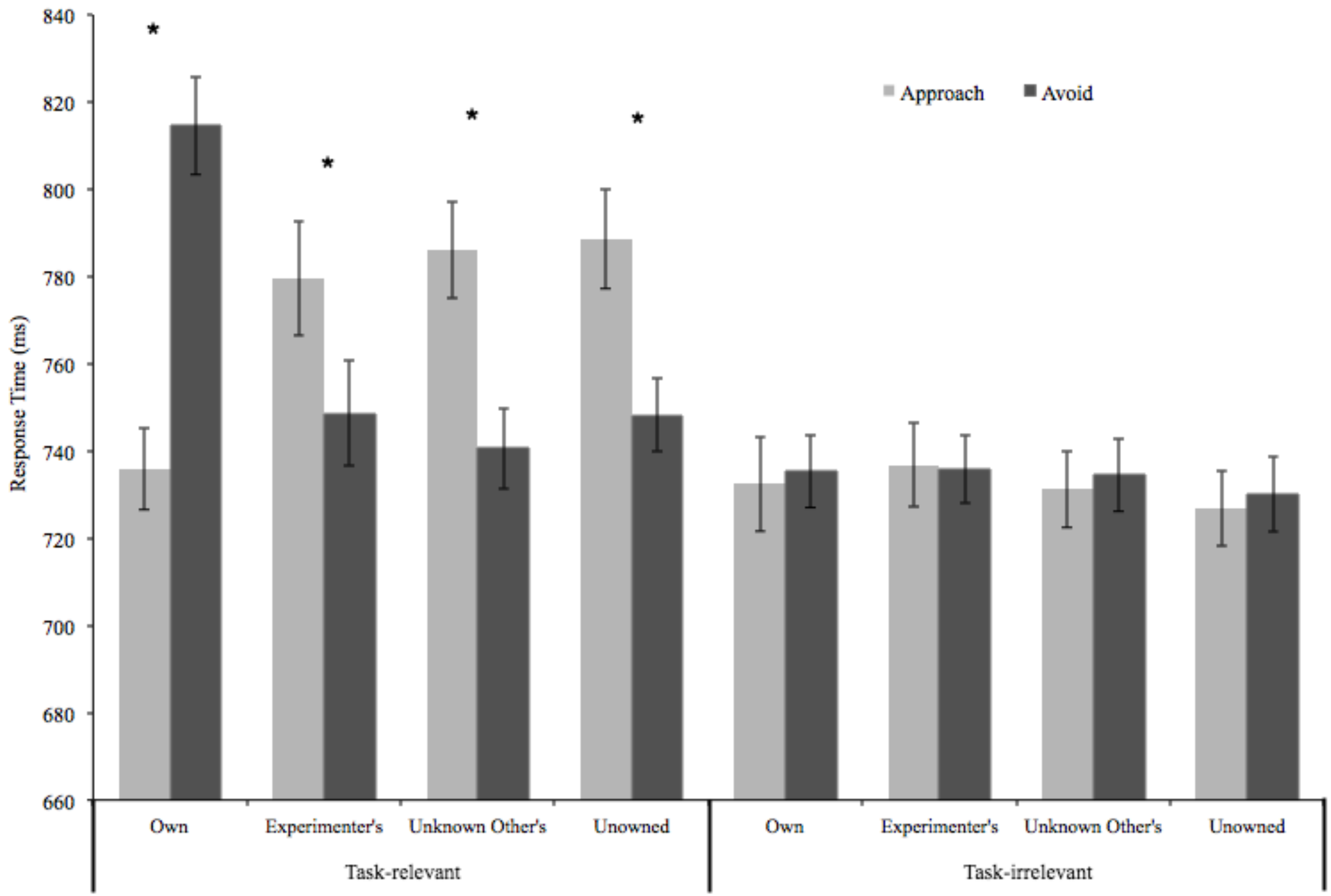

Figure 2. Mean response time (ms) for approach and avoidance movements by ownership status and block type. The error bars reflect the standard error calculated for within-subjects effects (Loftus & Masson, 1994). Asterisk denotes $p < .05$

Taken together, these findings support our predictions that approach is facilitated for self-owned objects; and avoidance facilitated for other-owned property. The finding of facilitated avoidance across all levels of other-owned property, including the unowned mug (although note that facilitated avoidance for experimenter's narrowly missed significance), was unexpected. It is unclear why this occurred, however, it may suggest that any item that is not self-owned holds negative valence for the observer; possibly induced by the task instruction to categorise the mugs as 'yours' and 'not yours', creating a crude self-other distinction.

Ownership as task-irrelevant

Akin to task-relevant performance, there was no significant main effect of action [$F(1,34) < 1$] or ownership status [$F(2.43, 82.57) <1$]. However, there was no significant action × ownership status interaction, $F(2.017, 68.563) = .068$, $p = .936$, $np^2 = .002$ (see Figure 2). Therefore, unlike performance in the explicit ownership categorization task, ownership status did not influence the production of approach and avoidance movements when responding to mug images on the basis of border colour. This lack of effect may suggest that ownership only facilitates congruent action performance when task-relevant. However, the lack of effect *may* be attributable to task requirements. For example, the ownership as task-irrelevant blocks required response on the basis of the colour of a border framing the mug and neutral image (grey square). The need to visually attend to the borders, rather than the mug (as in the task-relevant block), could have resulted in the failure to process the mug and identify ownership.

In addition, participants only had to contact the coloured border indicated by the task instruction, rather than select an appropriate response based on the presented stimulus. Response times were faster over all conditions of the irrelevant task, when compared with relevant block performance; suggesting the ownership irrelevant task was easier to complete; likely due to not requirement to select an appropriate response. Therefore, in Experiment 2, we modified the irrelevant task to more closely resemble the ownership categorisation blocks.

Experiment 2

In Experiment 2 we aimed to replicate our initial findings from the task-relevant condition of Experiment 1. To address the possibility that an absence of ownership effect in the task-irrelevant condition could be due to a failure to attend to the stimulus and select a response based on a stimulus feature; we reformulated the task, to require either an approach (touch mug) or avoid (touch square) movement depending on mug handle colour (e.g., if handle is purple, touch mug; if the handle is not purple, touch square).

In addition, due to a higher than anticipated number of false starts in Experiment 1 (initiating response prior to the go-signal, 300 ms after stimulus onset), suggesting that participants had prepared response prior to the go-signal, the response delay was removed. The task upon which we modeled ours required participants to explicitly evaluate whether they liked or disliked the stimulus (Bamford & Ward, 2008). No such subjective response was required in our study, therefore, the delay was considered obsolete for our purposes.

Method

Participants

Thirty undergraduate students from the University of East Anglia, naïve to the purpose of the study, volunteered in exchange for course credit. However two participants failed to attend for the second session and two participants' data was lost due to technology failure, leaving 26 (5 male; $M = 21.64$, $SD = 4.64$ years), who all reported having normal or corrected-to-normal vision and were right-handed.

Stimuli and Apparatus

The stimuli and apparatus were largely identical to that of Experiment 1, with the exception that three versions of each mug image were produced: no handle manipulation, orange handle, and purple handle.

Design & Procedure

The design and procedure was identical to that of Experiment 1, aside from the removal of the auditory go-signal, 300 ms after stimulus onset (see Figure 3). The ownership task-irrelevant block also differed; with participants instructed to touch the mug if the handle is orange, and touch the grey square if the handle is not orange (and vice versa for the remaining block).

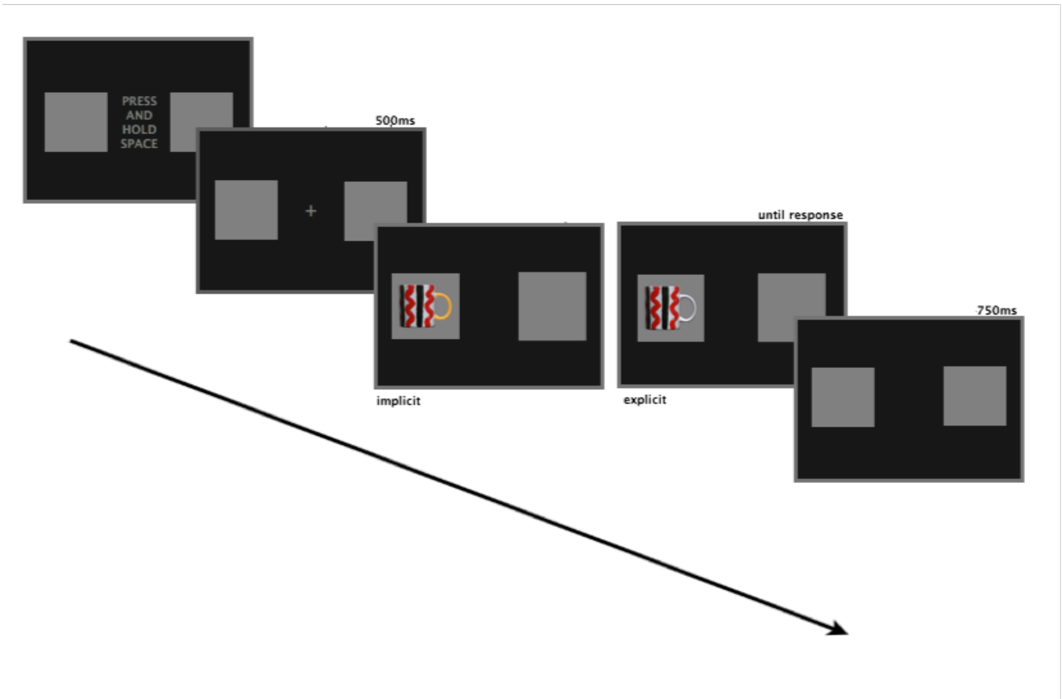

Figure 3. The time course of a trial for Experiment 2. Coloured borders framing the placeholders in Experiment 1 are absent; replaced with purple or orange swatches on the mug handles, in the task-irrelevant blocks only.

Results & Discussion

Data trimming and analyses were conducted in the same manner as Experiment 1; 0.43% of trials were removed due to incorrect responses, and 1.54% were excluded as outliers. Three participants' data was removed due to performing with an error rate above 15% within a single level of the ownership factor (due to limiting the number of trials per condition to compare to performance in the other levels, and being indicative of not attending to the task instructions). Response times were averaged per participant for each condition (see Table 1) and subjected to a 3-way ANOVA.

The 2 × 2 × 4 ANOVA revealed no significant main effect of task (ownership relevant vs. task-irrelevant), $F(1, 22) < .1$. Therefore, the amendments to the task-irrelevant blocks, implemented to ensure attention was oriented to the mug; and require response selection based on a mug feature (akin to the explicit ownership judgment required in the task-relevant blocks) abolished task differences in response time; suggestive of increased similarity of task requirements.

Table 1

Means and T-tests for simple main effects of ownership (response time for own, experimenter's, unknown other and unowned averaged across movement type) in the task-relevant condition of Experiment 2.

Comparison	*M* (*SD*)	df	*t*	*p*
Own - Experimenter's	855 (87); 818 (99)	22	6.65	.006 **
Own - Another's	855 (87); 829 (96)	22	5.05	.005 **
Own - Unowned	855 (87); 829 (97)	22	3.95	.004 **
Experimenter's - Another's	818 (99); 829 (96)	22	-2.29	.064
Experimenter's - Unowned	818 (99); 829 (97)	22	-2.78	.033 *
Another's - Unowned	829 (96); 829 (97)	22	.111	.913

Note. Standard deviations are displayed in parentheses. ** = *p* < *.01,* * = *p* < *.05.*

There was a significant main effect of action, $F(1, 22) = 12.22$, $p = .002$, $np^2 = .357$. Averaged over ownership and task, participants were significantly slower to perform avoidance movements (841 ms) compared with approach (824 ms). There was also a significant main effect of ownership [$F(3, 6) = 9.74$, $p = .001$, $np^2 = .307$]; participants were significantly slower to respond to their own mug (845 ms) compared with the experimenter's (828 ms), $t(22) = 4.845$, $p < .012$, unknown other's [830 ms; $t(22) = 3.867$, $p = .01$] and the unowned mug (828 ms; $t(22) = 3.962$ $p = .008$). All other comparisons were not significant ($p > .4$).

We also observed significant two-way interactions between task and action [$F(1, 22) = 6$, $p = .23$, $np^2 = .306$], task and ownership [$F(3, 66) = 9.7$, $p < .001$, $np^2 = .306$] and critically, ownership status and action [$F(1.66, 36.48) = 16.2$, $p < .001$, $np^2 = .424$]. However, akin to Experiment 1, the two-way ownership by action interaction were superseded by the significant three-way task × action × ownership status interaction, $F(1.85, 40.74) = 12.57$, $p < .001$, $np^2 = .36$. Therefore, two 2 (action) × 4 (ownership) ANOVA's were conducted for the relevant and irrelevant tasks separately.

Ownership as task-relevant

There was no significant main effect of action, [$F(1, 22) < 1.5$]; but there was a significant main effect of ownership [$F(2.13, 46.76) = 15.74$, $p < .001$, $np^2 = .417$]. Of less interest for our predictions, post-hoc comparisons (see Table 1) revealed that participants were significantly slower to respond to their own mug compared with the experimenter's, another participant's and the unowned mug. Participants were faster to respond to the experimenter's mug, compared with the unowned mug. There was no difference in response time between the mug belonging to another and the unowned or experimenter's mug. This lengthening of time to respond to the self-owned mug, averaged over action types, is led by the delay in avoidance response for self-owned objects (see Figure 4).

Central to our predictions, there was a significant two-way interaction between action and ownership status, $F(1.45, 31.85) = 17.22$, $p < .001$, $np^2 = .439$ (see Figure 4). Planned pairwise comparisons comparing mean approach response time with mean avoid response time for each level of ownership status was conducted. As predicted and in line with Experiment 1, participants were significantly faster to approach their own mug, compared with avoiding it, $t(22) = -6.9$, $p < .001$ (two-tailed); and significantly faster to avoid the mug belonging to an unknown other than approach it, $t(22) = 2.58$, $p = .017$ (two-tailed). However, the trend toward faster avoid actions (vs. approach) for the experimenter's mug observed in Experiment 1 dissipated, $t(22) = 0.96$, $p = .346$ (two-tailed). Also in contrast to Experiment 1, there was no significant difference when comparing approach with avoid time for the unowned mug, $t(22) = 0.16$, $p = .874$.

Comparing ownership level within each action type aids in identifying the abolishment of the effect within this experiment. Unlike Experiment 1, where participants were faster to approach own (vs. all other-owned levels) and faster to avoid all other-owned (relative to avoiding self-owned), approach was only faster for self-owned when compared with unknown other's [$t(22) = -2.117$, $p = .046$; all other self - other-owned comparisons $p > .4$, see Appendix B]. However, faster avoidance was observed for all other-owned levels (vs. self-owned, all comparisons = $p < .001$).

It is not clear why the compatibility effects observed in Experiment 1 failed to fully replicate, given that only the delay in movement onset (300 ms, in Experiment 1) was altered in Experiment 2. Given that 'automatic' affective priming in other task contexts is assumed be reflected up to a stimulus onset asynchrony (between prime and target judgment/stimulus) of less than 300 ms (Fazio et al., 1986; for a review, see Fazio, 2001), the findings from Experiment 2 may be more reflective of the true priming of motoric responses, rather than the response time differences possibly resulting from explicit effortful evaluation.

In addition, it is worth noting that the power achieved within Experiment 2 was less than that of Experiment 1. We conducted post hoc power analyses using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) with power set at 0.80 and α = 05, two-tailed. This illustrated that we only obtained 0.51 power (sufficient power is ruled to be 0.80, Cohen, 1988) for the effect size (dz = .44) for the approach own - approach unknown other's comparison in Experiment 2 (but we did achieve sufficient power for 'avoid own vs. avoid unknown other'). An N of 43 would be required to obtain sufficient power. In contrast, we obtained .97 (dz = .69) for the same approach comparison in Experiment 1. Thus, we cannot eliminate the possibility that we did not possess sufficient power to detect the effects obtained (in Experiment 1), within Experiment 2.

Ownership as task-irrelevant

A significant main effect of action [$F(1, 22) = 40.69$, $p < .001$, $np^2 = .649$], but not ownership [$F(3, 66) = 1.81$, $p = .153$, $np^2 = .076$] was observed. Participants were quicker to produce approach (820 ms), compared with avoidance (845 ms), responses. In contrast to Experiment 1, there was a significant two-way interaction between action and ownership, $F(3, 66) = 3.85$, $p = .013$, $np^2 = .149$. However, unlike the task-relevant block, all levels of ownership status (own, experimenter's, unknown other's and unowned) elicited significantly faster approach, compared with avoidance, responses ($p < .02$; see Figure 4). Two one-way repeated measures ANOVA's were conducted to explore the interaction.

The one-way 'Approach' ANOVA revealed a significant effect of ownership, $F(3, 66) = 4.43$, $p = .007$, $np^2 = .167$). Post-hoc comparisons indicated that participants were slower to approach the experimenter's, compared with the unowned mug [$t(22) = 3.75$ $p = .006$] and also slower to approach the mug belonging to another participant, compared with the unowned mug, $t(22) = 2.98$, $p = .035$. All other comparisons were non-significant, ($p > .2$).

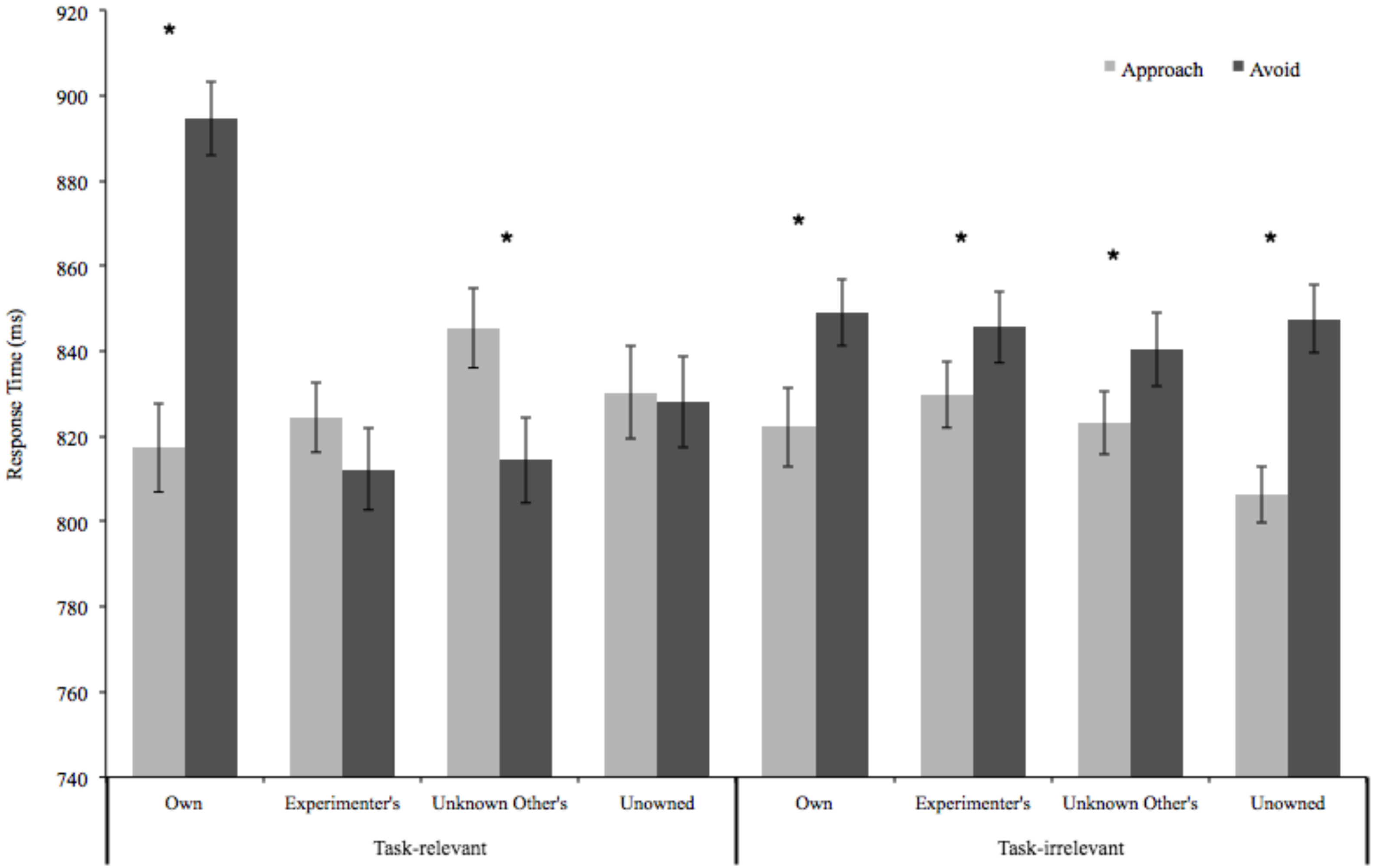

Figure 4. Mean response time (ms) for approach and avoidance movements by ownership status and block type. Error bars reflect within-subjects standard error (Loftus & Masson, 1994). Asterisk denotes $p < .05$

The one-way 'Avoid' ANOVA revealed no significant effect of ownership, $F(3, 66) = .70$, $p = .553$, $np^2 = .031$. Therefore, despite amendments in Experiment 2 to the task-irrelevant condition which ensured attention to the mug stimulus; and response on the basis of a stimulus feature (ultimately making the task more similar to the demands of the task-relevant blocks), there was still no significant difference when comparing approach and avoidance times for the own and unknown other's object. Although findings from the two block types are not directly comparable due to differences in the distribution of action for ownership level within blocks; we tentatively suggest that ownership *only* influences congruent action performance when task-relevant.

In summary, performance in the task-relevant blocks of Experiment 2 somewhat replicated Experiment 1. Consistent with our predictions, participants were significantly quicker to approach their own mug (but only relative to approaching the mug belonging to an unknown other) and quicker to avoid the mugs belonging to other individuals. One contextual factor worthy of note when considering the other-ownership effect identified (and in our initial pilot - Experiment 1) is the imbalance of stimulus probability for 'self' and 'other-owned' trials.

New findings published during the conduction of Experiment 2 indicated that increasing the probability of other-associated stimuli (relative to self-associated) in the label-shape matching task, discussed in Chapter 1, improves object categorization performance for other-associated shapes. However, time to respond to the self-shape pair was not affected by low frequency presentation; with a clear self-advantage still present (Sui et al., 2014). Although each level of ownership (own, experimenter's, other, unowned) was presented an equal number of times within Experiment 1 and 2; the task requirement to categorise stimuli according to 'mine' and 'not mine' (therefore, requiring three times as many 'not mine' categorisation responses per block) produces altered probability at a categorical level. Therefore, to examine whether the affective compatibility effects obtained for other-owned property in Experiment 1 and 2 are bound to differential stimulus probability, equal probability of responses for self and other-owned property was induced in Experiment 3 by only including two levels of ownership; self and unknown other.

Experiment 3

To establish whether the other-ownership compatibility effect elicited in Experiments 1 and 2 was a function of greater 'other-ownership' stimulus and response probability, Experiment 3 reduced the levels of other-owned stimuli, comparing approach and avoidance response time for only the self-owned and unknown other's mug. A secondary task was also included; recruiting 'typical' valenced pictorial stimuli (positive and negative), to compare typical affective compatibility effects (see Bamford & Ward, 2008; Chen & Bargh, 1999; Laham, et al., 2015; Rotteveel & Phaf, 2004) with those elicited by the ownership task. It was predicted that we would observe faster approach (vs. avoidance) for positive images, and vice versa for negatively valenced pictures.

Method

Participants

Thirty-eight right-handed students from the University of East Anglia were initially recruited and participated in exchange for course credit. However four individuals failed to attend the second experimental session. Data from the remaining 34 participants is reported (one male; *M* = 21.68, *SD* = 5.89 years).

Stimuli & Apparatus

Ownership stimuli. As in Experiment 1 and 2, participants decorated a mug with a design of their choosing in small group sessions. Participants took the mugs home to use and keep (*M* = 3.74, *SD* = 4.08 uses), before later returning with the mug to complete the task (*M* = 12.12, *SD* = 5.64 days owned). The processing of the mug images (own and unknown other's) was identical to that of Experiment 2.

Affective stimuli. Eight pictures (four positive, and four negative) were selected from the International Affective Picture System (IAPS; Lang, Bradley & Cuthbert, 2008). They were selected on the basis of a mean valence rating greater than 7 for positive stimuli, and less than 2.5 for negative images (see Table 2). Three versions of each image were produced: One with no colour alterations (however the image was cropped to replicate the size of the grey square in the ownership blocks), and two versions with a transparent orange and purple filter imposed upon the image.

Approach-Avoidance Task. A version of the task featuring the participant's own mug, a mug belonging to an unknown other participant, four positive and four negative valence images was produced. The task consisted of eight blocks (four task-relevant, four task-irrelevant) and four practice trials. The ownership relevant and irrelevant blocks were identical to those of Experiment 2 aside from only the 'own' and 'unknown other's' mugs being presented. In the relevant and irrelevant affective image blocks, participants were issued similar task instructions to those provided for the ownership blocks (i.e., 'if the image shown is negative, touch the image; if the image is positive, touch the plain grey square' and vice versa).

Table 2

Mean ratings for valence and arousal of affective image stimuli taken from the International Affective Picture System (Lang et al., 2008).

Mean Ratings for Valence	Valence	Arousal
Bunnies (1750)	8.28 (1.07)	4.1 (2.31)
Baby (2070)	8.17 (1.46)	4.51 (2.74)
Children (2345)	7.41 (1.72)	5.42 (2.47)
Romance (4599)	7.12 (1.48)	5.69 (1.94)
Dead cows (9181)	2.26 (1.85)	5.39 (2.41)
Bloody kiss (2352.2)	2.09 (1.5)	6.25 (2.1)
Sad child (2800)	1.78 (1.14)	5.49 (2.11)
Mutilations (3150)	2.26 (1.57)	6.5 (2.2)

Note. The images are identified by their numbers in the International Affective Picture System (Lang et al., 2008). Standard deviations are given in parentheses.

Participants completed 80 trials in each block (each mug image appearing 40 times, and each valenced image presented ten times, per block). Each mug and affective image appeared in each object position (left or right), and with each handle or filter colour (in the task-irrelevant blocks), an equal number of times, but identity (own vs. another's, or positive vs negative), position and handle or swatch colour was randomised within each block. Block order was counterbalanced across participants, however participants always completed the relevant and irrelevant blocks in succession. The affective image blocks were always completed after the ownership blocks.

Design & Procedure

The experiment adopted a 2 × 2 × 2 × 2 within-subjects design, manipulating stimulus type (ownership or affect), task type (task-relevant, task-irrelevant), stimulus (own vs unknown other's for the ownership blocks, positive vs negative for affect) and action (approach vs avoid). The dependent variable was response time recorded in milliseconds (ms). The procedure and task set up was identical to Experiment 2, with the addition of the positive and negative images blocks. The affective images blocks were always performed after the ownership blocks.

Results & Discussion

Trials with errors (0.44%) were removed. Four participants with an error rate above 15% within one level of the ownership factor, which limited the number of trials per condition to compare to performance in the other levels; and is also indicative of not attending to the task instructions, were excluded from the analysis. 1.15% of trials were classified as outliers, and removed. Two participants produced errors on more than 15% of trials, resulting in their data being eliminated. The remaining trials were averaged by task type, stimulus type and action (see Figure 5). Two 2 × 2 × 2 within-subjects ANOVAs were conducted to examine approach-avoidance effects in the ownership and affect blocks separately.

Ownership

The 2 × 2 × 2 ANOVA revealed no significant main effect of task, $F(1,28) < 1.5$. However, unlike Experiment 1 and 2; there was a significant main effect of ownership $F(1,28) = 8.725$, $p = .006$, $np^2 = .238$. Averaged across action and task type, participants were faster to respond to their own mug (875 ms) compared with the unknown other's (881 ms). The main effect of action was also significant, $F(1, 28) = 89.487$, $p < .001$, $np^2 = .762$; with participants generally faster to perform approach actions (857 ms) compared with avoidance (900 ms). There were also significant two-way interactions between task and action [$F(1, 28) = 9.689$, $p = .004$, $np^2 = .257$] and task and ownership [$F(1, 28) = 19.123$, $p < .001$, $np^2 = .406$].

Most relevant for the study predictions and in accordance with Experiment 1 and 2, we again observed a significant ownership and action interaction [$F(1,28) = 9.023$, $p = .006$, $np^2 = .244$]. However, as before, it was superseded by the significant three-way interaction between task, action and ownership status, $F(1, 28) = 11.048$, $p = .002$, $np^2 = .283$.

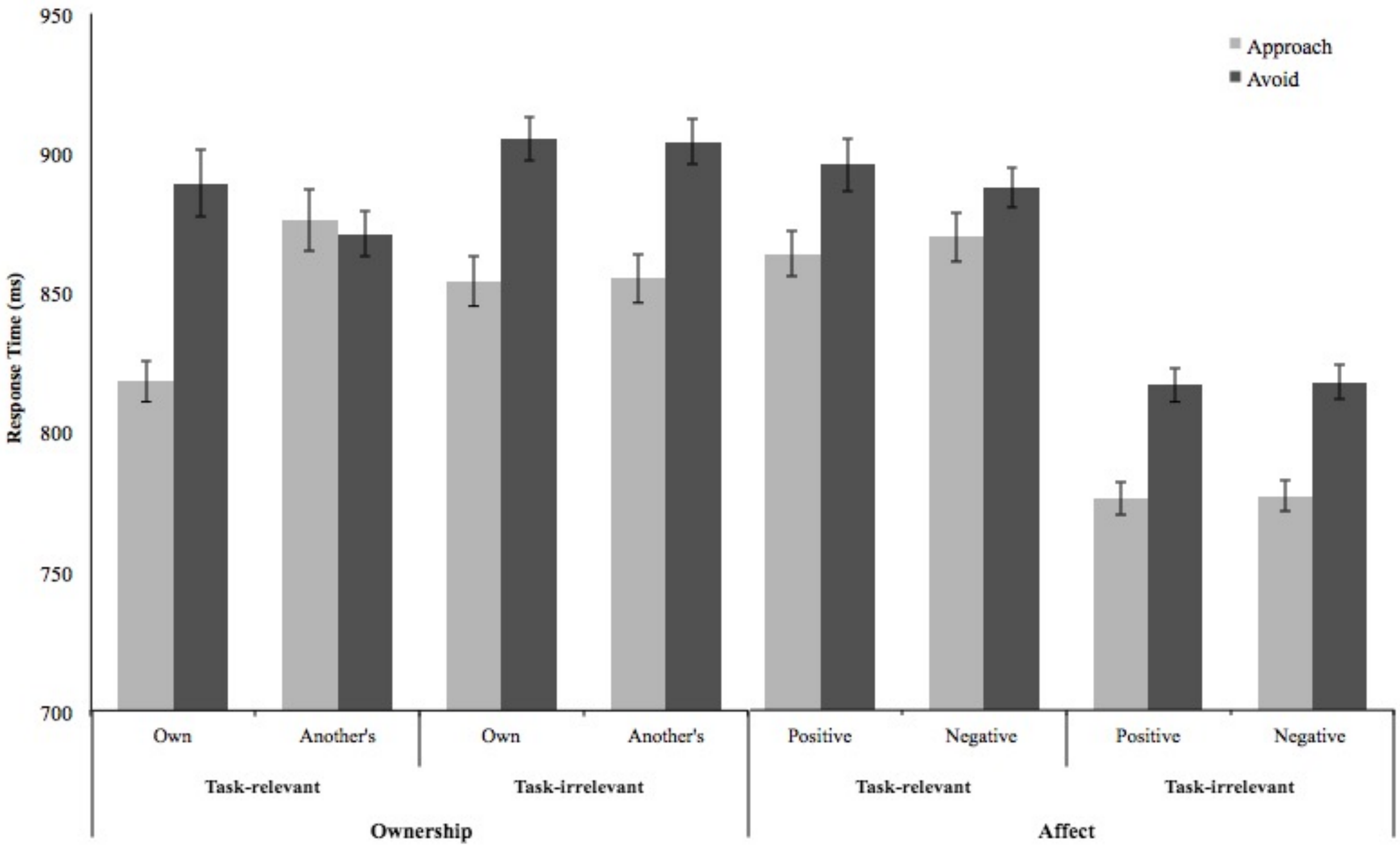

Figure 5. Average response times (ms) for approach and avoidance movements by stimulus type (ownership or affect), under task-relevant (explicit) and task-irrelevant (implicit) conditions. Error bars represent within-subjects standard error (Loftus & Masson, 1994).

To explore this, two 2 × 2 ANOVA's were conducted to separately explore the simple two-way interactions between ownership status and action for both the task-irrelevant and task-relevant conditions.

Ownership as task-relevant. The main effect of ownership was significant [F(1, 28) = 21.14, $p < .001$, $np^2 = .43$], with participants producing quicker responses for their own mug (M = 856 ms, SD = 90) compared with the unknown other's (M = 873 ms, SD = 101). Additionally there was a significant main effect of action, F(1,28) = 50.84, $p < .001$, $np^2 = .65$; participants were faster to perform approach (847 ms) compared with avoid movements (881 ms).

Of most interest, we again observed a significant two-way interaction between action and ownership status, F(1, 28) = 11.39, $p = .002$, $np^2 = .29$. Planned pairwise comparisons indicated that, again, participants were significantly faster to approach their own mug compared with avoiding it, t(28) = -5.81, $p = .002$. However, upon adjustment of stimulus probability (the removal of experimenter's and unowned levels of ownership), there was no significant difference for unknown other in this experiment, t(28) = .359, $p = .722$ (see Figure 5).

When comparing ownership for each action, participants were significantly faster to approach own (vs another's, t(28) = 4.312, $p < .001$, two-tailed), but despite a descriptive trend suggesting faster avoidance for another's compared with avoiding own, there was no significant difference [t(28) = -1.708 $p = .099$, two-tailed, see Figure 6]. The lack of effect for avoiding unknown other in this study, unlike Experiment 1 and 2, is suggestive of increased stimulus probability for other-owned objects acting as a mechanism in producing the affective compatibility effect previously observed. Note that we achieved adequate (98%) power for the approach own - approach unknown other comparison in the present study (unlike Experiment 2) but only 36% power (lower than the 80% threshold considered sufficient, see Cohen, 1988), for the avoid own avoid other comparison, with an N of 84 required to detect the observed effect size (dz = .32). Therefore, although we cannot rule out an underpowered design resulting in the failure to observe a significant effect for avoidance actions, the N required is reasonably substantial for a within subjects design, suggesting any effect to be observed is much smaller than that for approach behaviour observed within the current study.

Ownership as task-irrelevant. As in Experiment 2, there was a significant main effect of action [F(1, 29) = 85.61, $p < .001$, $np^2 = .75$]. Participants were faster to perform approach (860 ms) movements, compared with avoid (912 ms) responses. There was no significant main effect of ownership [$F(1, 29) = .51$, $p = .48$, $np^2 = .02$], nor ownership status by action interaction, $F(1, 29) = .16$, $p = .7$, $np^2 = .01$; again supporting our finding that ownership status only produces affective compatibility effects when it is task-relevant.

Affect

The 2 (task) × 2 (affect) × 2 (action) ANOVA revealed a significant main effect of task [$F(1,30) = 70.238$, p < .001, np2 = .701] and action [$F(1,30) = 71.349$, p = < .001, np2 = .704]. Participants were faster to respond in the affect as task-irrelevant (797 ms) compared with affect as task-relevant (880 ms) blocks; and faster to perform approach (822 ms) responses (vs. avoid; 855 ms). There was no main effect of affect [$F(1,30) < 1$], nor a two-way interaction between task and affect [$F(1,30) < 1$, $p > .5$].

Contrary to our prediction that we would observe faster approach responses for positive images (vs avoid), and faster avoid responses for negative images (vs approach); no significant two-way interaction was found between affect and action, $F(1, 30) = .249$, $p = .622$, $np^2 = .008$. Task × affect × action also failed to reach significance, $F(1, 30) = .301$, $p = .587$, $np^2 = .01$. Of less interest, there was a significant two-way interaction between task and action, [$F(1, 30) = 7.572$, $p = .01$, np2 = .202]. Post-hoc comparisons revealed that, in the task-relevant condition, participants were significantly quicker to approach objects than avoid them, t(30) = -7.45, $p < .002$). The same pattern was observed in the task-irrelevant condition, $t(30) = -9.252$, $p < .004$.

However, the *difference* between avoiding and approaching was significantly greater in the task-irrelevant (M = 40 ms, SD = 28) compared with the task-relevant (M = 25 ms, SD = 24), $t(30) = 2.752$, $p < .004$. There was no significant two-way interaction between task and affect [$F(1,30) < 1$, $p > .5$].

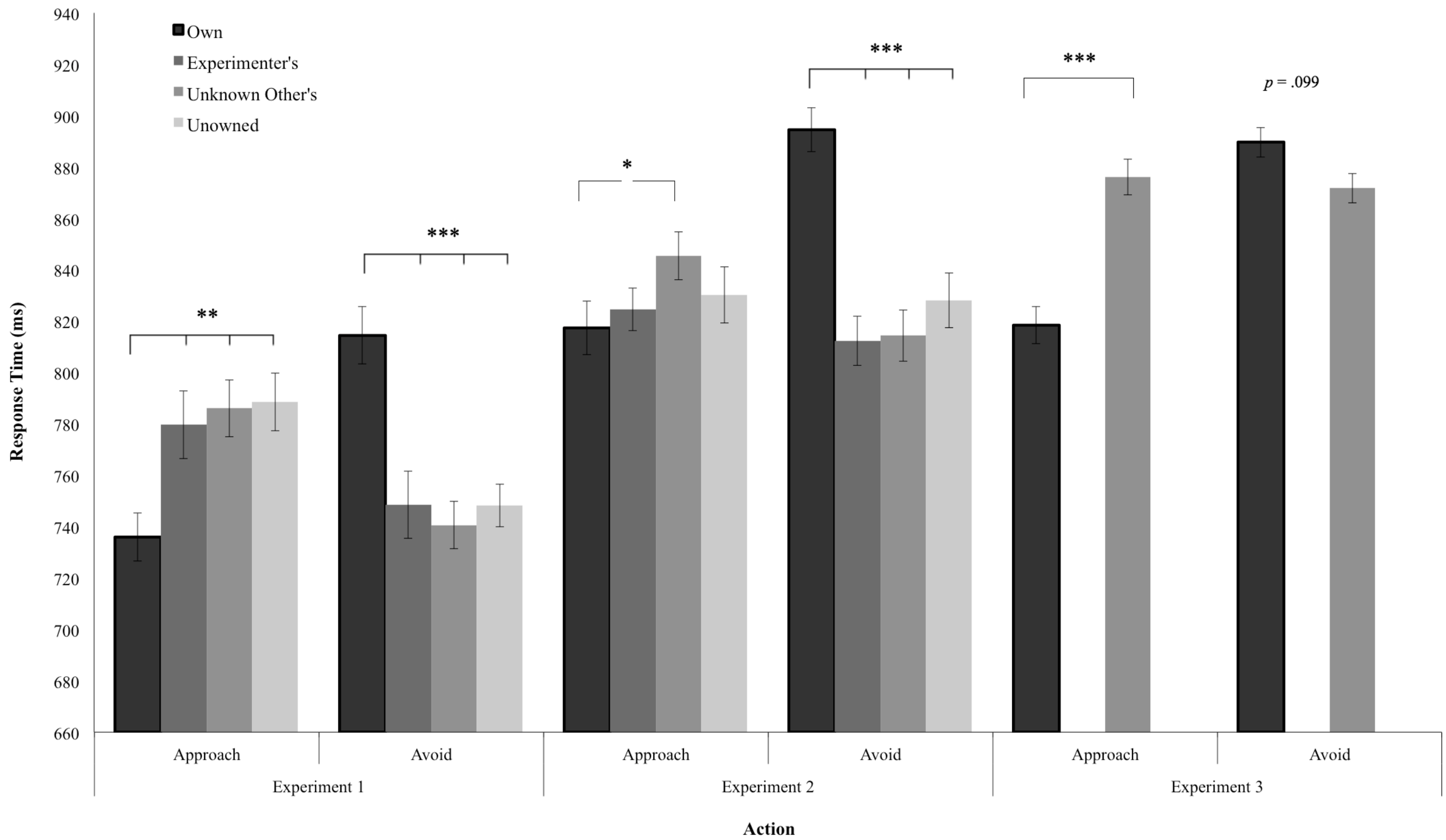

Figure 6. Average response times (ms) by movement type for each ownership level (task-relevant blocks) in Experiment 1, 2 and 3. Error bars represent within-subjects standard error (Loftus & Masson, 1994). *Note.* *** denotes $p < .001$, ** = $p < .01$, * = $p < .05$

General discussion

Previous findings investigating movement trajectories when reaching for, or interacting with, self and other-owned property, indirectly allude to the production of facilitated approach movements for self-owned objects (Constable et al., 2011; 2014; Sparks et al., 2016). Therefore, the experiments presented in the present chapter aimed to directly investigate whether affective compatibility effects, that is, facilitated approach responses for positively valenced objects, and facilitated avoidance responses for negative items, occur as a function of object ownership status; using a touchscreen paradigm based on that of Bamford and Ward (2008).

As predicted, and consistent with indirect evidence from kinematic studies (Constable et al., 2011; 2014; Sparks et al., 2016), across all three experiments, we observed evidence of approach facilitation for self-owned property (note in Experiment 2 this was only evident when compared with approaching the mug belonging to an unknown other), under conditions where ownership is task-relevant. Although present, evidence for facilitated avoidance movements in response to other-owned items was less robust. In the first two experiments, when more than one other-owned stimulus was presented, facilitated avoidance was observed when responding to the mug owned by another participant. However, emergent findings during the course of the testing of our paradigm indicated that increased stimulus probability facilitates response time for stimuli associated with 'other' (Sui et al., 2014). Although each stimulus level was presented an equal number of times in Experiment 1 and 2; we propose that the requirement to categorise stimuli as 'mine' and 'not mine' (resulting in the probability of categorising a stimulus as 'not mine' three times more often in Experiment 1 and 2) Therefore, we compared approach and avoidance for only the self-mug and unknown other's object in Experiment 3.

Under equal probability conditions, no significant affective compatibility effect for the other-owned mug was observed (but the compatibility effect for self-owned remained). Therefore, stimulus probability appears to be an important contextual factor mediating effects associated with responses to other-owned objects and shapes. However, given that increased stimulus probably facilitated categorization time in Sui et al. (2014); what is unclear is *how* increased probability of other-ownership within our task context (Experiment 1 and 2) differentially influenced the time taken to approach and avoid. On the basis of their findings that when presented with increased probability of self *and* other-owned shapes, the advantage for 'other' was abolished, Sui et al. (2014) proposed that stimulus probability acts to mediate expectancy (supposing that expectancies for self-shapes override other, even when the stimulus probability of both is equal). However, on the basis of increased expectancy for other-owned property; we might anticipate reduced response time for the unknown other's mug in general (for *both* movement types) under increased probability conditions (vs. equal probability conditions). However, there was no difference in approach time between Experiment 2 and 3 for unknown other (Experiment 2: 845 ms; Experiment 3: 876 ms, $p < .3$); with an increase only observed in time to avoid (Experiment 2: 814 ms; Experiment 3: 872 ms, $p = .05$) in Experiment 3. Therefore, stimulus probability appears to have selectively mediated the affective compatibility effect.

Under conditions where ownership was not task-relevant, but participants were instead required to attend to a physical feature of the mug stimulus (handle colour), no differences between approach and avoidance time as a function of ownership were observed. Time taken to avoid was slower than approach across ownership conditions in Experiment 2 and 3. Although caution should be executed in interpreting null effects, we tentatively suggest that this absence of effect when ownership is task-irrelevant indicates that the construct of ownership needs to be activated in order to influence action. This is in line with emergent findings that self-associated shapes are not be privy to the perceptual advantages observed under task-relevant conditions, when their self-relevant nature is irrelevant to the task judgment performed (see Liu & Sui, 2016). However, this is not unique to ownership, but the case for the influence of valence on approach and avoidance response tendencies in general. Across the literature, the elicitation of affective compatibility effects when stimulus valence is task-irrelevant is inconsistent (for example, see Klauer & Musch, 2002; although see Rinck & Becker, 2007).

What remains unclear from the present experiments is the extent to which the observed facilitation of approach (vs. avoidance) for self-owned property may result from attentional processes; rather than action facilitation. The nature of the recruited task confounded attentional processes; requiring participants to attend to the stimulus (mug), and either respond by touching its location, or avoid it, requiring them to re-orient their attention in order to contact the plain grey square. This design is reminiscent of the peripheral cueing task, where participants are presented with an initial cue, followed by a target in the same (valid), or different (invalid), location. This typically leads to faster responses for valid cue trials than invalid (Posner, 1980). However, when the cues are self-relevant (own name) and other-relevant (other's name), the cueing effect is larger for self-relevant information (Alexopoulos, et al., 2012). Alongside a significant number of other studies observing an influence of self-relevance (e.g., Gray et al., 2004; Mack & Rock, 1998), and self-object association (Truong et al., 2016; Turk et al., 2011; Yanouskaya et al., 2016) on attention; this enhanced distracting effect of self-cues does suggest that our effect could alternatively be interpreted as a result of attention being 'held' by the self-owned mug, and subsequently increasing the delay observed when avoiding the self-owned mug. However, this effect is unlikely to completely account for our findings, given the trend toward faster avoidance, than approach, for other-owned items in Experiment 1 and 2. This suggests some delay in preparation of a response for the 'cued' location, which, we would anticipate under an attentional explanation, would always be faster than production of avoidance responses (as in the implicit task blocks).

The failure to replicate the typical affective congruency effect that Bamford and Ward (2008) observed in our adapted version of their paradigm is potentially surprising, and could also be interpreted as further support for an attentional (rather than motoric) account of our effect. However, methodological differences may account for the absence of typical affective congruency effects. In the current study, the affect blocks were always completed secondary to the ownership task. Therefore, continued practice may have masked differences. Additionally, to more closely mimic the ownership blocks, fewer stimuli with were used in our task (four of each valence category; in contrast to 40 in Bamford & Ward, 2008). Repeated exposure to the same valenced stimuli reduces physiological measures of arousal (for example, see Bradley, Lang & Cuthbert, 1993) and implicit and explicit evaluations of stimulus valence (Dijksterhuis & Smith, 2002). Therefore, the repetition of stimuli in our affect task may have reduced perceived valence, abolishing congruency effects.

In summary, we have presented evidence that has attempted to directly support the notion that self-owned property facilitates approach actions, relative to avoidance. Due to methodological factors, the extent to which the observed approach facilitation is underpinned by embodied affective motor processes and attentional capture cannot be ascertained. However, this finding remains interesting in further demonstrating self-ownership biases; regardless of mechanism. In addition, our evidence also indicates that, to a less robust degree, avoidance actions are facilitated for other-owned property, relative to approach. However, this effect was dependent on greater stimulus probability for ‘other-owned’ objects. This finding further supports the notion that, beyond ownership purely operating as another facet of advantaged processing of self-relevant stimuli; the socially situated construct of ownership, and its associated norms and consequences, influences action performance (for example, see Constable et al., 2011; 2014). Future research considering affective compatibility effects and ownership should endeavour to reduce attentional confounds in the task paradigm recruited, and establish how stimulus probability mediates affective compatibility responses.

Chapter 3. Affective compatibility: Away from screens, toward kinematics

The experiments presented in the previous chapter aimed to provide the first direct evidence that ownership facilitates approach for self-owned property; and avoidance for other-owned objects. An advantage when producing approach movements for self-owned mugs (vs. avoidance) was observed. However, the design confounded attention allocation and response processes. Therefore, as previously discussed, the slowing of avoidance for self-owned items (which required participants to re-orient their attention away from the stimulus), which is suggestive of an affective compatibility effect; could also reflect difficulty in disengaging attention from the self-owned stimulus in order to produce the avoidance movement; or a combination of both processes. Establishing another instance of attentional biases for self-ownership would further add to findings illustrating the facilitated attentional processing of, and orienting to, objects associated with the self (for example, see Truong et al., 2016; Turk et al., 2011; Yanouskaya et al., 2016). However, this was not the aim of the present thesis. Therefore, to clarify whether self-ownership produces a pattern of motor responses consistent with affective compatibility, Experiment 4 recruited an Approach-Avoidance task design that does not confound attentional factors.

A number of paradigm options were considered, for example, a more normative joystick or keyboard-based response process (for example, see Chen & Bargh, 1999). However, alongside identifying additional self-ownership effects, another core aim of the experimental work presented was to further delineate the effects that other-ownership elicits. In the experiments presented in the last chapter, evidence for the facilitation of avoidance movements, relative to approach, for other-owned stimuli, was inconsistent. Some degree of facilitated avoidance for other-owned objects was observed in Experiment 1 and 2, when more than one level of 'other' ownership was utilised. However, in Experiment 3, when participants only responded to their own, and an unknown other's, object, this effect dissipated.

The difficulty in identifying robust other-ownership effects, when compared with self-ownership advantages, is not surprising; such effects are subtle and susceptible to contextual mediation. For example, the care taken to interact with a mug belonging to another is abolished when the owner is known, but not present, during action performance (Constable et al., 2014). This suggests that other-ownership needs to be salient in order to influence action performance. The increased weighting of other-owned stimuli within Experiment 1 and 2, relative to Experiment 3, may have boosted the salience of other-ownership. Although we cannot fully identify how altered stimulus probability, which facilitates the identification of other-owned stimuli (Sui et al., 2014), would differentially affect avoidance and approach movements, it may, through increased salience of ‘other’ ownership; facilitate production of congruent movements (avoidance) in increased other-owned probability conditions. As the influence of ownership status on action appears to be contextually sensitive, and we wished to directly assess approach and avoidance behaviour alluded to during tasks requiring interaction with real objects within a workspace; we opted to replicate this environment.

Therefore, we produced a version of an approach-avoidance task with similar contextual properties to tasks that have indirectly identified potential affective congruency effects (see Constable et al., 2011; Constable et al., 2014; Sparks et al., 2016). Akin to Experiment 1 to 3, participants decorated a coffee mug with a design of their choosing alongside the experimenter. They took their mug home to use, before returning to the laboratory with their mug to complete the task. In Experiment 4, participants again categorised the mugs (own and experimenter’s) as ‘mine’ and ‘not mine’, however in response to its ownership they pushed the physical mug away, or pulled it toward, the torso; to occlude a white target, as quickly as possible.

We predicted that participants would be faster to initiate and execute approach movements (toward the body) for their own mug, relative to approaching the experimenter's Despite an absence of consistent effect for the experimenter’s mug in Chapter 1 (Experiment 1 & 2); given that the owner (experimenter) was present during task execution, and owner presence appears to predict reticence to interact with another’s property during interaction with 3D objects (Constable et al., 2014), we tentatively predicted that participants would be faster to initiate and execute avoidance movements for the experimenter’s mug (vs. approach).

Experiment 4

Method

Participants

Constable et al.'s (2011) N of 19 was used to determine the minimum acceptable sample size for the present study. Allowing for some attrition, thirty students were initially recruited from the University of East Anglia and participated in return for payment. However, three participants failed to attend the laboratory after decorating their mug. Two participants' data was lost due to recording errors; therefore, data from the remaining 25 is reported (two male; *M* = 20.88, *SD* = 7.1 years). Participants were right handed, had normal or corrected-to-normal vision and no history of neurological or motor disorders. Participants were naïve to the purpose of the experiment and gave informed consent. The study was approved by the University of East Anglia School of Psychology Research Ethics Committee.

Apparatus and Stimuli

Stimuli. Participants attended small group sessions to decorate a white ceramic coffee mug, which they were instructed to take home and use (*M* = 2.18, *SD* = 4.4 uses), prior to returning to the laboratory with their mug to complete the task (*M* = 15, *SD* = 3.32 days after painting). The researcher also decorated a mug for inclusion in the task. Before the task, four adhesive felt furniture floor protector pads were attached to the base of the mugs to protect the table surface and facilitate ease of movement.

Experimental set-up. Participants were seated in an ambiently lit room at a 60 x 120 cm grey table, with a black start button (button box 3.2 x 2.2 cm, 1 cm diameter) placed on the front edge. Two white target crosses were fixed to the surface of the table (each arm being 9 cm long, with a width of 1 cm), positioned 40 cm apart, one toward the near edge of and one toward the far edge (see Figure 7). The mug, either belonging to the participant or the researcher, was positioned centrally between the targets. To ensure accuracy of mug placement, ultraviolet (UV) markings were used to indicate placement position with a handheld UV light used to expose these markings to the experimenter during placement.

Participants wore PLATO LCD goggles to control vision while the object was placed, between trials (Translucent Technologies, Toronto, Canada). Six Qualisys Oqus (Sweden) motion-tracking cameras recorded the X, Y, Z positions at a sampling frequency of 179 Hz of the infrared reflective markers attached to the centre of the nail of the right index finger, and a marker on the mug. A custom designed program written in Matlab (The MathWorks, USA) was used to control trial order, the goggles and recordings.

Design

We employed a 2 × 2 design, manipulating ownership (own or experimenter's) and action (approach or avoid). Participants reached toward the mug (own and experimenter's) and pushed or pulled it to cover the target, depending on task instruction. In the congruent block, participants pushed the mug away from their body (avoid) if the object belonged to the experimenter, and pulled it toward the self (approach) if it was theirs. In the incongruent block, they performed the opposite task. Participants completed both blocks; order was counterbalanced.

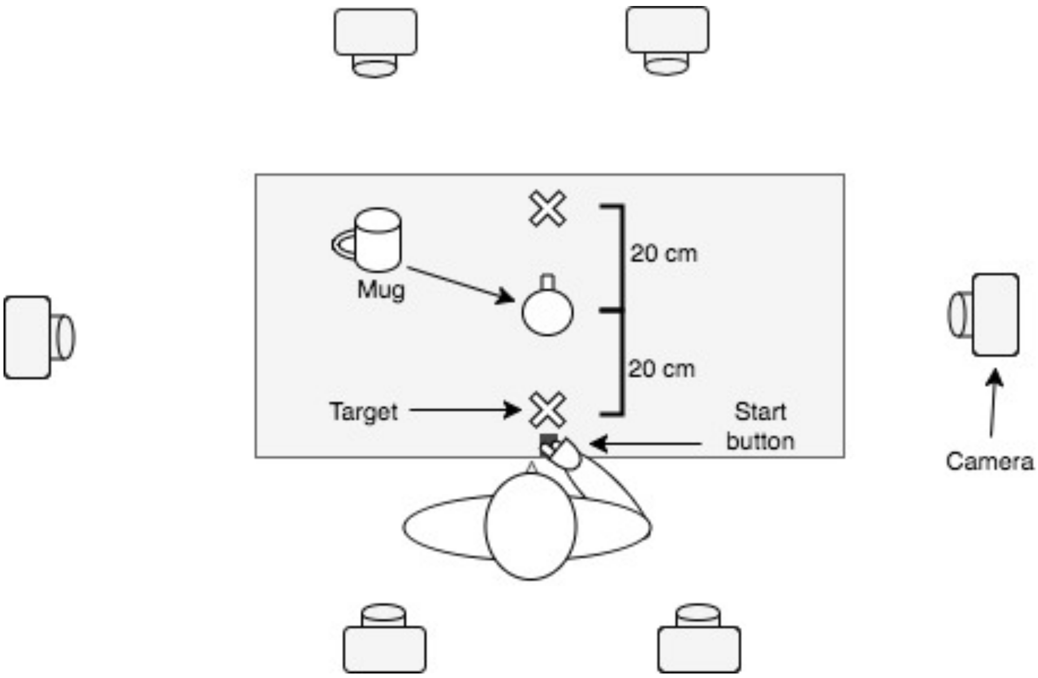

Figure 7. Experimental set-up (not to scale). Participants were seated at a table in front of a black push button. Two white targets; 40 cm apart, were adhered to the table surface. The mug was placed centrally between the two targets (centre of mug placed at 20 cm).

The dependent variables recorded were; reaction time (time in ms from goggles opening to release of start button), reach movement time (time in ms between release of push button and contact with the mug), reach peak velocity (maximum velocity in mm/s during the index movement), We also recorded movement time and peak velocity for the mug movement; and calculated the difference between start and end position of the mug on y (distance moved).

Procedure

Mug painting and preparation. Participants and the experimenter initially decorated a coffee mug, with a design of their choosing, using ceramic paints. Once painted, participants took their mug home to use. Participants were informed they would need to recall instances where they used it upon returning to the laboratory. This manipulation was intended to encourage use. Upon returning with their mug, adhesive felt furniture floor protector pads were attached to the base of the participant and researcher's mug, and an IRED placed on the mug, and the participant's index finger, to allow the tracking of movement.

Task. The task consisted of two blocks; instructions were delivered verbally prior to the block commencing. Participants were required to quickly pull the mug toward themselves, occluding the white target cross, if it belonged to them; and push the mug away from themselves if it belonged to the experimenter (and vice versa for the remaining block). Block order was counterbalanced across participants.

At the beginning of each trial, the PLATO goggles were in an opaque configuration, restricting vision for the participant while the experimenter placed the mug. Each trial started with an auditory cue from the researcher ("ready?"), signaling that the participant should press and hold down the start button. The researcher then manually triggered the trial, resulting in the PLATO goggles becoming transparent, allowing the participant to view the table and mug. When ready to perform the movement, the participant released the push button and executed the push or pull. Once completed, the researcher triggered the PLATO goggles to return to their opaque configuration, preventing vision, while the next trial was set up. There were 48 trials in a block (24 per condition), 96 total, and up to 5 practice trials, only practicing until they became comfortable with the procedure. Trial order was randomised. The task took approximately twenty-five minutes to complete.

Data processing. The raw data from the index and mug IREDs was filtered using a low-pass second-order Butterworth filter with a cut-off frequency of 10 Hz and analysed using customised software written in Matlab. Missing marker coordinates were infilled using linear interpolation, however this was not successful on 26 trials, these were excluded from analysis. The beginning of the 'reach toward mug' component was defined using a velocity-based criterion of 50 mm/s, the end of the index portion was defined as when the mug reached a velocity of 50 mm/s. Mug push or pull was segmented by a start and end velocity of 50 mm/s. A trial-by-trial inspection was carried out to remove any trials in which participants did not complete the task correctly (performing the wrong direction movement) resulting in the exclusion of 17 trials from further analysis. Three participants' data was removed due to performing more than 15% erroneous responses.

For each trial the analysis program extracted the following dependent measures: reaction time (time in ms from the goggles revealing the display to release of start button), reach movement time (time in ms between start and end of movement as defined by the velocity-based criteria described above), mug movement time, reach peak velocity (maximum velocity in mm/s during index movement time), mug peak velocity. We also calculated the distance moved from the start and end position of the mug on Y (depth).

Results

The dependent measures were calculated for every trial and then averaged for each condition (see Table 3), and subjected to a 2 × 2 (ownership × action) ANOVA. Significant values were set at $p < .05$.

Table 3

Means by condition for dependent measures. Standard deviations in parentheses.

		Action	
	Ownership	Approach	Avoid
RT (ms)	Own	276 (74)	311 (108)
	Experimenter's	303 (107)	282 (78)
MT (ms)	Own	458 (98)	408 (78)
	Experimenter's	472 (91)	411 (85)
PV (mm/s)	Own	1667 (340)	1632 (292)
	Experimenter's	1655 (296)	1625 (332)
Mug MT (ms)	Own	435 (94)	458 (85)
	Experimenter's	432 (76)	454 (95)
Mug PV (mm/s)	Own	832 (192)	749 (152)
	Experimenter's	837 (183)	770 (182)
Distance moved (mm)	Own	196.8 (6.8)	192.8 (8.1)
	Experimenter's	195.4 (7.3)	193.6 (6.2)

Note. RT (reaction time), MT (movement time), PV (peak velocity), Mug MT (movement time of mug), Mug PV (peak velocity of mug movement)

Reaction time (movement initiation)

There was no significant main effects of ownership [$F(1, 21) < 1$ $p > .7$, or action [$F(1, 21) = 1.470$, $p = .239$, $np^2 = .065$]. However, central to our predictions, the ownership × action interaction was significant [$F(1, 21) = 4.832$, $p = .039$, $np^2 = .187$].

Pairwise comparisons revealed that, as predicted, participants were significantly faster to initiate approach movements for self-owned mugs, compared with commencing approach for the experimenter's, $t(21) = 2.111$, $p = .047$ (two-tailed). Although failing to reach significance, there was a trend toward faster initiation of avoidance for experimenter's (when comparing initiation of avoidance for self-owned; see Figure 8), $t(21) = 1.865$, $p = .076$ (two-tailed).

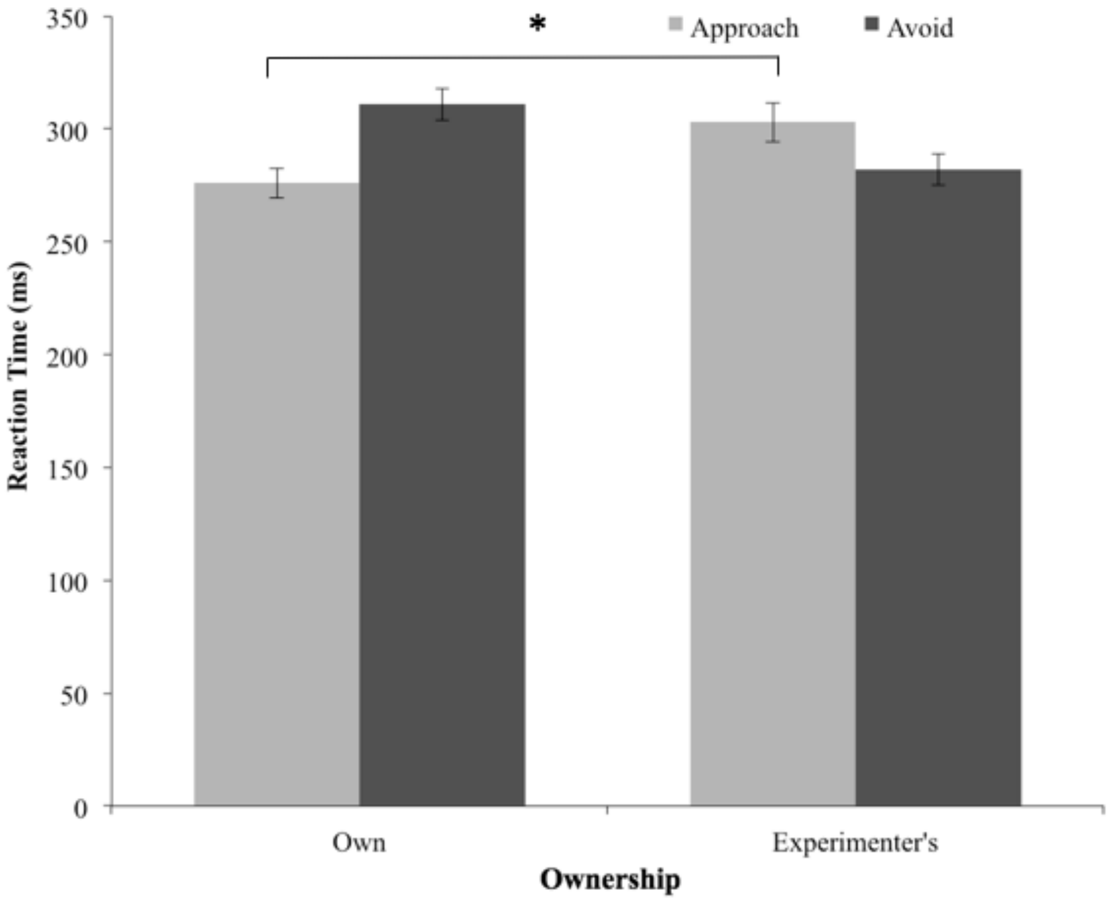

Figure 8. Average time taken to initiate movement for approach and avoidance movements, by ownership status (own and experimenter's). Error bars represent within-subjects standard error (Loftus & Masson, 1994). Asterisk denotes $p < .05$.

Reach toward mug

Movement time. There was a significant main effect of ownership on reach movement time [$F(1, 21) = 5.103$, $p = .035$, $np^2 = .195$]. Averaged over movement type, participants were faster to reach toward their own mug ($M = 434$, $SD = 83$) than the experimenter's ($M = 441$, $SD = 85$). There was also a significant main effect of action [$F(1, 21) = 84.881$, $p < .001$, $np^2 = .802$]. Participants were faster to reach toward the mug when they were about to perform an avoid action ($M = 410$, $SD = 79$), compared with approach ($M = 465$, $SD = 90$). However, the ownership × action interaction was not significant, $F(1, 21) = .267$, $p = .611$, $np^2 = .013$.

Peak velocity. There was no significant main effects of ownership [$F(1, 21) = .935$, $p = .345$, $np^2 = .043$], action [$F(1, 21) = 2.915$, $p = .102$, $np^2 = .122$], nor ownership × action interaction [$F(1, 21) = .004$, $p = .950$, $np^2 < .001$].

Mug movement

Movement time. There was a significant main effect of action on time taken to move the mug, $F(1, 21) = 16.842$, $p < .001$, $np^2 = .457$. Participants were slower to push the mug away from the body ($M = 456$, $SD = 89$), compared with pulling it toward the body ($M = 434$, $SD = 83$). Contrary to our predictions that participants would execute actions with more care during interactions with the experimenter's mug, there was no significant effect of ownership [$F(1, 21) = 1.315$, $p = .264$, $np^2 = .059$], nor a significant ownership × action interaction, $F(1, 21) = .019$, $p = .892$, $np^2 < .001$.

Peak velocity. There was a significant main effect of action on peak velocity [$F(1, 21) = 37.843$, $p < .001$, $np^2 = .643$. Participants reached greater peak velocity when pulling the mug toward the body ($M = 834$, $SD = 181$), compared with pushing away ($M = 760$, $SD = 162$). Again, we failed to observe greater care taken with the experimenter's (vs. self-owned) mug: The main effects of ownership [$F(1, 21) = .935$, $p = .345$, $np^2 = .043$], and ownership × action [$F(1, 21) = .279$, $p = .603$, $np^2 = .013$] were not significant.

Distance moved. There were no significant main effects or interactions for movement distance [$F(1, 20) < 2$, $p > .07$].

Discussion

The present study aimed to disentangle the influence of attention from motoric response processes underlying the robust approach advantage observed for self-owned property in Experiments 1 to 3. As we were also interested in effects elicited by other-ownership which may be best elucidated using real motor movements in response to physical objects (Constable et al., 2011; 2014; 2016); Experiment 4 investigated approach and avoidance responses via the performance of real motor movements; pulling the mug toward, or pushing it away, from the torso; with motion tracking used to record movement parameters. Importantly for the aims of the present thesis, subtle differences in movement initiation time *are* supportive of a motoric affective compatibility effect for self-owned property. Counter to our predictions, we failed to elicit a robust effect for other-ownership.

In accordance with Experiments 1 to 3, participants were significantly quicker to initiate their movement (reaction time) when required to bring their own mug toward the body (approach); compared with approaching the experimenter's. Somewhat surprisingly, there was no difference as a function of ownership in the kinematics of the actual object interaction phase of the movement. That is, there were no spatial or temporal differences in participants' manipulation of property as they moved it toward or away from the self. Nevertheless, as there was no requirement to re-orient attention in order to produce the avoidance response in the current paradigm (unlike Experiments 1 to 3), this difference in reaction time *can* be more confidently attributed as an embodied motoric response to self-owned property; akin to differentiation in the execution approach and avoidance time for objects of differing valence (for example, see Chen & Bargh, 1999).

Given that the manner, or at least degree, in which differential reward or affective value contributes to self-object biases is still unclear (Sui et al., 2015; Sui & Humphreys, 2015b; Sui & Humphreys, 2015c); the present findings which are, albeit indirectly, suggestive of a relationship between ownership and stimulus value reiterate the need for continued consideration of the interactivity of affect or reward in ownership representations and biases. Although not of primary concern in the present thesis (due to the inherently confounded nature of real world experiences of ownership with other factors; and the desire to maintain such conditions for the elucidation of more subtle other-ownership effects); we note that the manner in which ownership was manipulated (customisation of a mug, which was then taken home to use) potentially confounds effects of preference, choice and familiarity with that of ownership. Therefore, a logical next step for follow up research is to explore whether this affective compatibility pattern is obtained when removing these intertwined variables.

Despite a descriptive trend toward the reverse pattern of response facilitation for the mug belonging to the experimenter (faster initiation of avoidance movements vs avoiding own), there was no significant difference in time to initiate avoidance movements, relative to avoiding own. Note that we also failed to observe consistent compatibility effects for the *experimenter's* property in Chapter 2 (see Experiment 1 and 2). However, we elected to maintain the use of the experimenter as the level of other-ownership in the current paradigm, rather than extend the use of 'unknown other' included in Chapter 2; due to the consistency of previously identified embodied effects for experimenter-owned possessions in real world object interactions, and the apparent importance of owner presence in such contexts (Constable et al., 2011; 2014; 2016). Our failure to elicit robust embodied effects for property owned by the experimenter reflects an unexpected difference between the work of Constable and the findings of the present thesis. It is unclear *why* their recruitment of the researcher was successful in eliciting deviation in mug positioning from the torso (which we interpreted to reflect avoidance processes for others' property); while we failed to observe significant effects for property belonging to the experimenter.

However, note that limited statistical power may have played a role in limiting the significance of some of the statistical comparisons conducted. A post hoc power analysis revealed that the effect size (dz) of the pairwise comparisons (reaction time) for approach own vs. approach experimenter's ($dz = .45$) and avoid own vs avoid experimenter's ($dz = .42$) required a sample size of 41 and 53, respectively, to obtain statistical power at the recommended .80 level (Cohen, 1988).

Given the lack of spatial and temporal differentiation during the mug movements within the current study (although note with regards to spatial effects that participants had to achieve accuracy by occluding a target in the present paradigm; no accuracy requirements were present in Constable's lifting task), it is perhaps possible that the spatial deviations observed in Constable's work do not in fact reflect avoidance behaviour, as we initially proposed. Alternatively, although difficult to quantify; perhaps researcher characteristics and their dyadic behaviour with participants mediates the elicitation of such effects. Given that we achieved more robust results for property belonging to an unknown other in Chapter 2; a follow up study, recruiting the present task with this level of other-ownership would aid in beginning to disentangle whether there is a lack of response congruency effects for property belonging to another; or whether the experimenter (or some feature of the experimenter) tempered other-owned effects in the current work.

On the basis of our findings from the present chapter, and those of Chapter 2, target-directed action processes appear to be most robustly influenced by self-ownership (at least in the presence of its ecologically relevant contaminants, such as choice and preference). Given that self-owned property permits and requires action, this is perhaps unsurprising. Therefore, we began to consider action contexts where other-ownership cues may possess greater salience for the actor than self-ownership.

One possible context, that we frequently encounter, may be limb navigation of the environment in the presence of obstacles. Alongside the mediation of distance from the torso as a function of ownership, Constable observed that individuals temper their interactions with others' property (vs. their own), appearing to result from the desire to take care of others' belongings, in order to maintain good social relationships with owners (Constable et al., 2011; Constable et al., 2014). Interestingly, this mediation of temporal signatures of lifting movements that alluded to greater care was dissociable from the spatial differences in drawing self and other-owned property near the body. As discussed in more detail in the upcoming chapter, obstacles within the environment are encoded, and subsequent reaching movements adjusted, in relation to their consequences of collision. Given that previous work suggests that individuals take greater care when interacting with another's property (Constable et al., 2011; Constable et al., 2014), other-owned objects serving as an obstacle during reaches for a target object may differentially influence reach execution (vs. reaching in the presence of self-owned obstacles); in order to prevent collision, and its social consequences.

Chapter 4. Avoiding ownership: Obstacle avoidance

As discussed in Chapter 1, most research investigating the processing and effects of ownership has focused on biases associated with self-ownership (for example, see Cunningham et al., 2008; 2013; van den Bos et al., 2010; Sui et al., 2012; 2013; Sui & Humphreys 2015a; Turk et al., 2011; Truong et al., 2016). When other-ownership has been considered of interest in itself (rather than functioning as a less salient comparison level), including the experimental work previously presented in this thesis, it has been explored in the context of action performance when interacting *with* (lifting, moving) objects (Constable et al., 2011; 2014; 2016). Akin to the effects that self-ownership has been found to exert on perceptual, attentional and mnemonic processes, the work presented within this thesis has observed that target-directed action processes appear to be more robustly influenced by self-ownership (vs. other-ownership, at least in the presence of its ecologically relevant contaminants, such as choice and preference). Given that self-owned property permits and requires action, this is perhaps unsurprising.

As Constable's work has illustrated that the embodied visuomotor effects elicited by other-ownership are contextually sensitive (Constable et al., 2011; 2014; 2016), we began to consider action contexts where other-ownership cues may possess greater salience for the actor than self-ownership. One possible context that we frequently encounter may be limb navigation in the presence of obstacles. We reside in cluttered environments, where we often need to act upon objects in the presence of non-target items, owned by ourselves, but also belonging to others. For example, when having coffee with friends we must navigate their, and our own, coffee cups when retrieving the sugar. Most of the time we successfully achieve this without colliding with other objects within the space.

Recent findings that identity-related features of obstacles (such as its fragility, see Kangur, Billino & Hesse, 2017) alter reach trajectories, alongside Constable's observation that individuals temper their interactions with others' property (vs. their own), appearing to result from the desire to take care of others' belongings, in order to maintain good social relationships with owners (Constable et al., 2011; Constable et al., 2014), is suggestive of the need to explore the possible effects of other-ownership on obstacle avoidance behaviour. Other-owned objects serving as an obstacle during reaches for a target object may differentially influence reach execution (vs. reaching in the presence of self-owned obstacles); in order to prevent collision, and its social consequences. Although much is known about our general ability to plan and execute movements while avoiding obstacles, whether ownership may mediate movement kinematics within this action context has yet to be explored; but would allow further exploration of the limited evidence for the 'care' effect for other-ownership (Constable et al., 2011; 2014).

Obstacle avoidance

Our ability to avoid obstacles is achieved by altering the temporal and spatial parameters of our movements; with movement times increasing, and the trajectory of the acting limb deviating, to increase the distance of the arm from the obstacle(s). This occurs even when the obstacles do not physically obstruct the movement (Biegstraaten, Smeets, & Brenner, 2003; Chapman & Goodale, 2010a; Dean & Bruwer, 1994; Grimme, Lipinski, & Schoner, 2012; Kritikos, Bennett, Dunai, & Castiello, 2000; Menger, Van der Stigchel, & Dijkerman, 2013; Mon-Williams & McIntosh, 2000; Mon-Williams, Tresilian, Coppard, & Carson, 2001; Tipper, Howard & Jackson, 1997; Tresilian, 1998; Tresilian, Mon-Williams, Coppard, & Carson, 2005). These effects remain in open loop conditions (without vision), where visual feedback of the hand and objects is unavailable during the reach, but available during the movement planning stage (for example, see Chapman & Goodale, 2008). Therefore, obstacles must be represented at the planning stage, rather than merely responded to via visual feedback during execution.

It is theorised that these effects result from non-target objects being treated as physical obstacles, with movements preplanned to maintain a preferred distance between the limb and the obstacle, to avoid knocking them over (Tresilian, 1998). Evidence supports this account, as the risk of collision increases, for example, when obstacles are placed closer to the reaching limb, greater alterations in movement time and trajectory deviations are observed (Chapman & Goodale, 2008; Mon-Williams et al., 2001; Tresilian, 1998). In addition, obstacles placed beyond the target do not produce the same effects on reach behaviour, likely because there is no real risk of collision (Chapman & Goodale, 2008). Changing the starting posture of the limb to heighten the risk of collision, rather than workspace layout, has also been found to influence reach behaviour (Menger, Van der Stigchel, & Dijkerman, 2012). However, all obstacles placed close to the target within the workspace do not have the same degree of effect on our movements; obstacles on the right side have a greater influence compared with obstacles on the left side (Chapman & Goodale, 2008). This side effect results from participants commonly using the right hand to respond during tasks; ipsilateral objects appearing on the outside of the limb place greater constraints on the movement compared with the contralateral object, on the inside of the acting limb. When participants respond using the left hand, regardless of handedness (ruling out motor lateralisation), the effect is observed with the left obstacle (Menger et al., 2013). This further supports the hypothesis that the spatial and temporal characteristics of movements are altered to avoid collision.

To understand how obstacle avoidance is so efficiently achieved, the two visual streams hypothesis, proposing that one stream (dorsal) serves ‘vision for action’ and the other (ventral), underpins ‘vision for perception’, must be explored (Goodale & Milner, 1992, Milner & Goodale, 1995; Milner & Goodale, 2006; Milner & Goodale, 2008). This theory proposes that the ventral and dorsal stream of visual processing, although utilising the same inputs from early visual areas, processes visual information in different ways for different purposes.

The ventral stream processes information to form perceptual representations, containing characteristics of objects and their spatial relations within the environment, enabling us to consciously think about objects and perform perceptual judgments. The wealth of findings demonstrating that self-ownership influences early visual perception illustrates the effect ownership exerts on the ventral processing pathway (see Schäfer et al., 2015, Sui et al., 2012; 2013, Sui & Humphreys 2015a). In contrast, the dorsal stream processes visual input ‘online’ to guide skilled actions, such as reaching and grasping objects. Milner and Goodale proposed this stream does not rely on high-level mental representations of objects to guide action, but encodes information about the size and shape of the object, to purely guide movement. The dorsal stream is believed to underpin our fine-grained ability to quickly and accurately avoid obstacles (Goodale & Milner, 1992; Milner & Goodale, 2008).

Evidence for the role of the dorsal stream in obstacle avoidance arises from studies with patients who exhibit damage to regions involved in the dorsal network and display disordered obstacle avoidance (Rice et al., 2008; Schindler et al., 2004). Conversely, obstacle avoidance is preserved in those with damage to ventral stream structures, but an intact dorsal stream network (for example, see Rice et al., 2006). Taken together, such findings provide support for the role of the dorsal stream in obstacle avoidance.

Non-dorsal features and obstacle avoidance

Obstacle avoidance seems to depend upon dorsal stream functioning, however, there is some evidence indicating that higher order semantic features of obstacles, assumed to be encoded by the ventral stream, may also influence the movement path. Indeed, Milner and Goodale (2008), concede that the ventral stream, and the mental representations of objects embedded with semantics which result from this processing network, can play a role in the ability to avoid obstacles. This is especially likely in circumstances when the obstacles' semantic and material properties need to be considered, such as reaching in the presence of fragile or dangerous items. However, despite Goodale and Milner's (2008) claim that the ventral stream may have a role to play in obstacle avoidance, whether higher-order properties of the obstacles to be avoided influence movement parameters has not received much attention in the literature.

In a recent study, De Haan, Van der Stigchel, Nijnens, and Dijkerman (2014) observed that obstacle identity influenced reach trajectory. De Haan et al. (2014) placed a full or empty water glass on either the right or left side of space, at a distance halfway between the start position and the target button. Participants were instructed to make a speeded response with their right hand, moving from the start position and pressing the push button target. They found that individuals' movements veered further away from the full water glass obstacles, compared with the empty water glass, but only when the obstacle appeared on the right side of space (it was more obstructing). This study suggests that, under some conditions, object identity (a higher order feature of objects) does influence avoidance responses; likely resulting from the differing consequences of colliding with an empty glass compared with one containing water.

Similarly, Kangur et al. (2017) observed slower movement times when participants reached for a target in the presence of a more fragile obstacle (martini glass) compared with a less fragile item (lager glass). Although both objects were made of glass, the martini glass can be perceived as more fragile because its shape makes it more prone to fall and break if contacted by the arm. Participants' maintained the same distance (trajectory) from the obstacle for both the lager glass and martini glass as the hand passed by the obstacle, but given the narrow stem of the martini glass compared with the lager glass, this suggests that participants did maintain more distance from the martini glass.

The findings of both De Haan et al. (2014) and Kangur et al. (2017) demonstrate that higher-order knowledge about the identity and fragility of objects (attributable to ventral stream perceptual processes), and what this knowledge informs us about the consequences of colliding with the item, shape avoidance processes. Ownership status is another important feature of obstacles that may similarly alter trajectories through its effects on the consequences of collision. However, ownership knowledge cannot be 'obtained' or influence avoidance behaviour through dorsal stream processing, as it is not a physically perceivable property of the object, instead requiring higher-order representations in order to identify the ownership status. Akin to differing consequences of collision if we were to collide with a full compared with an empty water glass (De Haan et al., 2014), the cost of collision (in terms of maintaining good social relationships), with an object belonging to another may be greater than the cost of ‘bumping into’ our own possessions, and therefore alter the temporal and spatial parameters of movements. In addition to extending findings concerning the influence of ownership on action mechanisms, manipulating ownership as another higher-order feature of objects in obstacle avoidance tasks informs us, more generally, about how features outside dorsal stream processing influence this phenomenon.

Therefore, the three experiments presented within this chapter aimed to elucidate whether the ownership status of obstacles (own or experimenter’s) mediates spatial and temporal parameters of reaching movements. Broadly, we predicted that participants would take more care when performing reaches in the presence of an obstacle owned by the experimenter, due to the greater possible costs of collision, observable through greater deviation away from the obstacle and increased movement time for the obstacle belonging to the experimenter, compared with self-owned obstacle trials.

Pilot study

An initial pilot study was conducted to establish whether a less typical task set-up, where participants reached over obstacles (that should not physically obstruct the reaching movement), would elicit obstacle avoidance effects observed in more standard paradigms that require the participant to reach between obstacles (for example, see Chapman & Goodale, 2008). Rather than recruit a standard paradigm, this set-up, adapted from Verheij, Brenner, and Smeets (2014), was trialed to allow the coffee mugs previously recruited as owned objects to be utilised. Previous research indicates that shorter obstacles do not produce the same degree of avoidance behaviour in paradigms requiring the participant to reach between obstacles (Chapman & Goodale, 2008), and the mugs are comparatively shorter than the obstacles traditionally used in such tasks (for example, 25 cm tall cylinders, Chapman & Goodale, 2008). However, Verheij et al. (2014) observed that very short obstacles altered movement performance when placed underneath the acting limb, rather than to the side. Therefore, the task appeared to possess greater suitability for the obstacle height.

Participants performed reach-to-grasp movements, grasping the centre of a white cylinder (target). Decorated coffee mugs functioned as obstacles in the task, with their own or the experimenter’s mug appearing in the movement path, placed between the start position and target. To act as a baseline, reaches in the presence of no obstacle were also performed. Participants performed the reaches in open loop (no vision) conditions. Open loop performance of obstacle avoidance tasks results from the use of obstacle avoidance paradigms with patient samples, to assess whether damage to dorsal areas impacts movement planning (for example, see Schindler et al., 2004). No vision conditions ensure deficits in movement planning, as a result of dorsal stream damage, can be isolated from deficits in the online control of movements (Chapman & Goodale, 2010a). Akin to Chapman and Goodale (2008), we opted to implement the open loop nature of performing an obstacle avoidance task in a non-patient sample, to assess whether ownership was encoded during movement planning, rather than potentially influencing the online control element of movement.

The movements were recorded using motion-tracking equipment to analyse spatial and temporal movement parameters. We predicted that the recruitment of taller obstacles in our task (compared with Verheij et al., 2014) may potentially elicit more robust avoidance effects, and that movement time would be reduced, and reach height at the obstacle location increased, for experimenter versus self-owned obstacles.

Method

Participants

Ten participants (two male; *M* = 19.56, *SD* = 1.42 years) were recruited from the University of East Anglia and participated in exchange for curricular credit. Participants were right handed, as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971; see Appendix A), had normal or corrected-to-normal vision, reported no history of neurological or motor disorders, and were naïve to the purpose of the study.

Apparatus and Stimuli

Participants were seated in an ambiently lit room alongside a 60 x 120 cm grey table, with a black start button (button box 3.2 x 2.2 cm, button 1 cm diameter) placed 20 cm to the right and 10 cm in front of their trunk. A target (white cylinder; 24 cm tall, 5.5 cm diameter) was fixed to the table, 40 cm from the start button. On obstacle trials, the obstacle (mug, experimenter's or own) appeared between the start button and target, with the centre of the mug placed 22 cm from the start position and the handle pointing toward the target (not visible from the start position, see Figure 9).

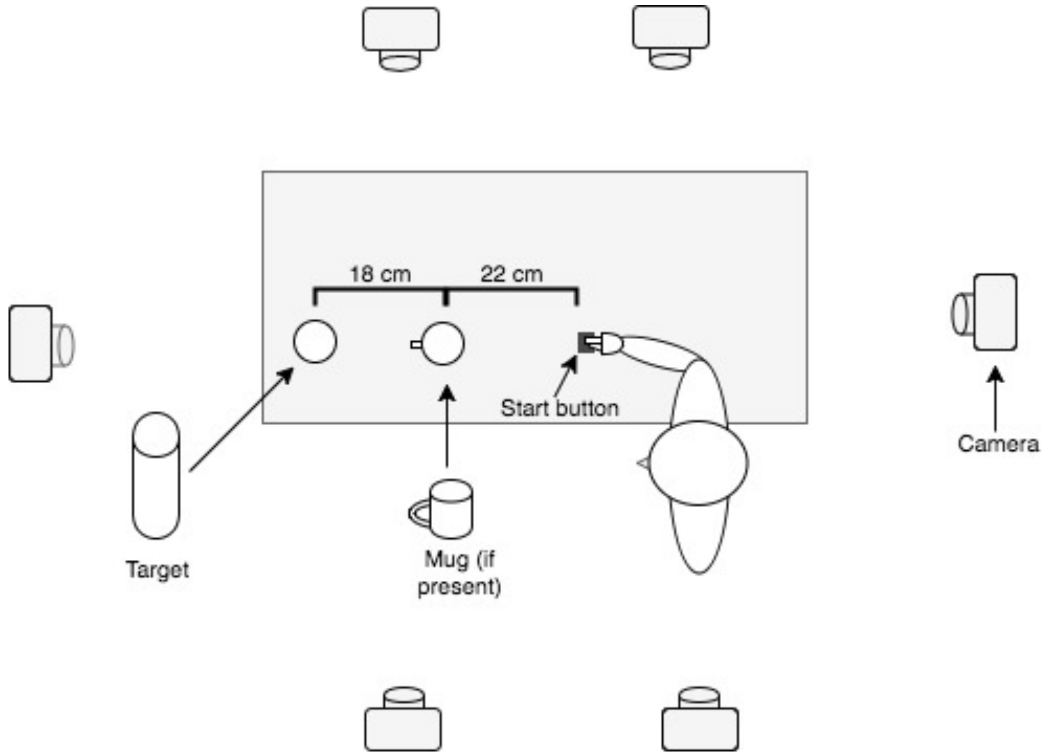

Figure 9. Experimental set up of the pilot study (not to scale).

Participants wore PLATO LCD goggles to control visual feedback (Translucent Technologies, Toronto, Canada). Six Qualisys Oqus (Sweden) motion-tracking cameras recorded the X, Y, Z positions at a sampling frequency of 179 Hz of the infrared reflective markers attached to the centre of the nail of the right index finger, thumb and wrist. A custom designed programme written in Matlab (The MathWorks, USA) was used to control trial order, the goggles, and recordings. The obstacles were white coffee mugs (9.5 cm tall, 8 cm diameter), one belonging to the experimenter and one to the participant, hand painted by the participants and experimenter with personalised designs. The participants took their mugs home to use (M = 5.67, SD = 5.34 uses) before bringing them back for part two of the experiment, where plastic furniture buffer pads were attached to the base of each mug, to minimise auditory cues that may have revealed obstacle placement.

Design

A one-way within-subjects design was implemented, with obstacle status manipulated. Participants reached over an obstacle (mug) belonging to themselves, the experimenter, or performed reaches with no obstacle. Participants painted the mug in stage one of the study, which they took home and used for a week prior to the experimental task.

The dependent variables recorded were; reaction time (time in ms from goggles becoming translucent to release of start button), movement time (time in ms between start and end of movement), peak velocity (maximum velocity in mm/s during the movement), time to peak velocity (time in ms from start of movement to peak velocity), and Z @ 220 (the height, z, deviation in mm when the hand passed over the middle of the obstacle [i.e., 220 mm in depth (Y) from the start button]).

Procedure

Ownership assignment. Prior to the experimental task, participants attended the lab in small groups to decorate their coffee mug with a design of their choosing, applied using ceramic paints. Participants could keep the object after the experiment, and took the mugs home to use.

Task. Participants had to perform a simple reach-and-grasp task, in the presence of no obstacle, self-owned, or experimenter-owned obstacle. Each trial started with the goggles in the opaque configuration, allowing the researcher to place one of the obstacles, if required. The experimenter gave an auditory signal to the participant to press and hold down the start button with their index finger and thumb in a precision grip formation (pinched). The researcher then triggered the trial to start, causing the goggles to become transparent, enabling the participant to see the target and obstacle (if present). The participant was instructed to release the button and grasp the target (cylinder) with their thumb and index finger, at a natural movement speed. They were informed that sometimes there would be other objects present on the table, but they were to ignore these objects and grasp the target. Upon release of the push button (i.e., movement initiation), the goggles became opaque, resulting in the participant completing the grasping action without visual feedback of the hand, obstacle and target (in open loop).

Participants completed 42 trials, with 14 repetitions of each of the 3 obstacle configurations (no obstacle, own, experimenter's) in a randomised order. Before the experiment the participants completed a maximum of 10 practice trials. The task took around fifteen minutes to complete.

Data processing. The raw data recordings were examined for missing data points, and linear interpolation was used to complete missing coordinates. However, due to camera positioning issues, some index marker frames could not be interpolated. Therefore, the wrist marker was selected for subsequent data analysis. A trial-by-trial inspection was conducted to eliminate trials where the participant completed the task inappropriately (such as commencing the reach movement before the goggles had opened to revealed the display), resulting in 19 trials being removed from further analysis.

The raw data from the infrared reflective marker positioned on the wrist was filtered using a low-pass second-order Butterworth filter, with a cut-off frequency of 10 Hz, and analysed using customised code written in Matlab (The MathWorks, USA). The beginning and end of each movement was defined using a velocity-based criterion of 50mm/s. The trajectories were translated, such that the first reading of the wrist marker using the velocity-based criterion was taken as the origin of the trajectory for X and Z (i.e. 0, 0, in 3D Cartesian space, X = horizontal, Z = vertical). However, to allow for the analysis of Z deviation at Y coordinates corresponding to obstacle location, the original Y coordinates of the wrist IRED were used (as the wrist marker trajectory started in negative coordinates, with the start button calibrated as 0). Trajectories were normalised to movement time such that they had 100 position measurements, allowing for averaging.

For each trial the following measures were calculated: reaction time (time in ms from trial commencement to button release), movement time (time taken between the start and end of movement, with the start and end defined by the velocity criteria stated above), time to peak velocity (time taken in ms from movement start [based on velocity criteria] to peak velocity), peak velocity (maximum velocity in mm/s achieved during movement) and the Z coordinate @ 220 (the height Z-deviation in mm when the wrist passed above the obstacle position [i.e., 220 mm in depth (Y) from start button]).

Results & Discussion

All dependent measures were calculated for every trial, and then averaged for each condition (see Table 4), and subjected to a one-way within-subjects ANOVA. Where sphericity assumptions were violated, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. Post-hoc comparisons were Holm-Bonferroni corrected and significant values were set at $p < .05$ (two-tailed).

Kinematic measures

There was a significant effect of obstacle (own, experimenter's or no obstacle) on reaction time, F (2, 18) = 4.987, p = .019, ηp^2 = .357. Post-hoc comparisons revealed that participants were significantly slower to commence their movement in the no obstacle condition (M = 390, SD = 87 ms), compared with when the experimenter's mug was present (M = 348, SD = 90 ms), t(9) = 4.1, p = .003 (two-tailed). There were no significant differences when comparing reaction time for own vs no obstacle (M = 362, *SD* = 99 vs *M* = 390, *SD* = 87 ms), $t(9) = 1.574$, $p = .150$ (two-tailed); and experimenter's vs own (*M* = 348, *SD* = 90 vs *M* = 362, *SD* = 99 ms), $t(9) = 1.234$, $p = .248$ (two-tailed). This unanticipated effect may be a result of the lower frequency of no obstacle trials, occurring on one third of trials, compared with an obstacle being present for two thirds of trials.

Table 4

Means by obstacle condition (Own, Experimenter's No Obstacle) for each dependent measure.

Dependent measure	Condition		
	Own	Experimenter's	No obstacle
Reaction time (ms)	362 (99)	348 (90)	390 (87)
Movement time (ms)	643 (99)	656 (116)	651 (106)
Peak velocity (mm/s)	1527 (255)	1490 (260)	1469 (247)
Time to PV (ms)	289 (39)	289 (40)	293 (46)
Z-deviation @ 220 (mm)	148.2 (13.1)	148.4 (12.8)	116.5 (31.3)
Z @ 400 (mm)	118.4 (12.6)	120.4 (13.2)	95.9 (29)

Note. Standard deviations are displayed in parentheses.

Contrary to our prediction that the temporal elements of movements would be increased when reaching in the presence of an obstacle and mediated by ownership status, there was no significant effect of obstacle on movement time, $F(2, 18) = .763$, $p = .481$, $\eta p^2 = .078$, peak velocity [$F(2, 18) = 2.480$, $p = .112$, $\eta p^2 = .216$], or time to peak velocity [$F(1.174, 10.565) = .304$, $p = .629$, $\eta p^2 = .033$]. This absence of effect is surprising. Although Verheij et al. (2014) did not observe consistent mediation of movement time as a function of reaching in the presence of an obstacle or not, other obstacle avoidance task set-ups do frequently elicit differences in peak velocity and movement time, with movements slowed when reaching in the presence of an obstacle, particularly on the right hand side (e.g., Chapman & Goodale, 2008; Chapman & Goodale, 2010). The obstacles recruited in the current study were three times taller (9 cm vs 3 cm) than those used by Verheij et al. (2014), therefore, we anticipated they would be more likely to alter measures of performance time, with a slowing of movement execution to decrease the risk of collision. However, this was not the case here.

Spatial measures

For each participant, trajectories were averaged across trials for each condition, before being averaged and plotted per condition across all participants (see Figure 10). When analysing the Z-deviation at Y = 220, the depth (Y) that the middle of the obstacles appeared, there was a significant influence of obstacle, $F(1.037, 9.331) = 17.934$, $p = .002$, $\eta p^2 = .666$.

Pairwise comparisons revealed that, in line with our predictions, participants passed over the obstacle location significantly lower in the no obstacle present ($M = 116.5$, $SD = 31.3$ mm), than experimenter's ($M = 148.4$, $SD = 12.8$ mm), t(9) = 4.278, $p = .006$ (two-tailed), and own obstacle condition ($M = 116.5$, $SD = 31.3$ mm), $t(9) = 4.243$, p = .006 (two-tailed). However, despite anticipating that participants would further increase the distance between the limb and the mug in the experimenter's condition, to minimise the risk of collision with an object owned by another individual, there was no significant difference in Z deviation when comparing own ($M = 148.2$, $SD = 13.1$) and experimenter's ($M = 148.4$, $SD = 12.8$, $t(9) = .171$, $p = 1$). Unlike the absence of an effect of obstacle on movement time, peak velocity, and time to peak velocity, there was an effect of obstacle on the wrist height at the placement position, with the wrist positioned higher when an obstacle was present (replicating Verheij et al., 2014). However, there was no significant effect of obstacle ownership.

To assess whether our non-significant effect of obstacle ownership could be due to a lack of statistical power, we conducted post hoc power analyses using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) with power set at 0.80 and $\alpha = 05$, two-tailed. This illustrated that to obtain sufficient power (0.80, Cohen, 1988) for the effect size (dz = .05) obtained for the Z-deviation of own vs experimenter's obstacle, a sample size of 2652 would be required, compared with a sample of 7 required when comparing own vs no obstacle (dz = 1.34, 96% power obtained within the present study). Thus, it is unlikely that our failure to identify an effect here can reasonably be attributed to the limited sample size, as the N required is unreasonably large for the discipline, and especially the design in question.

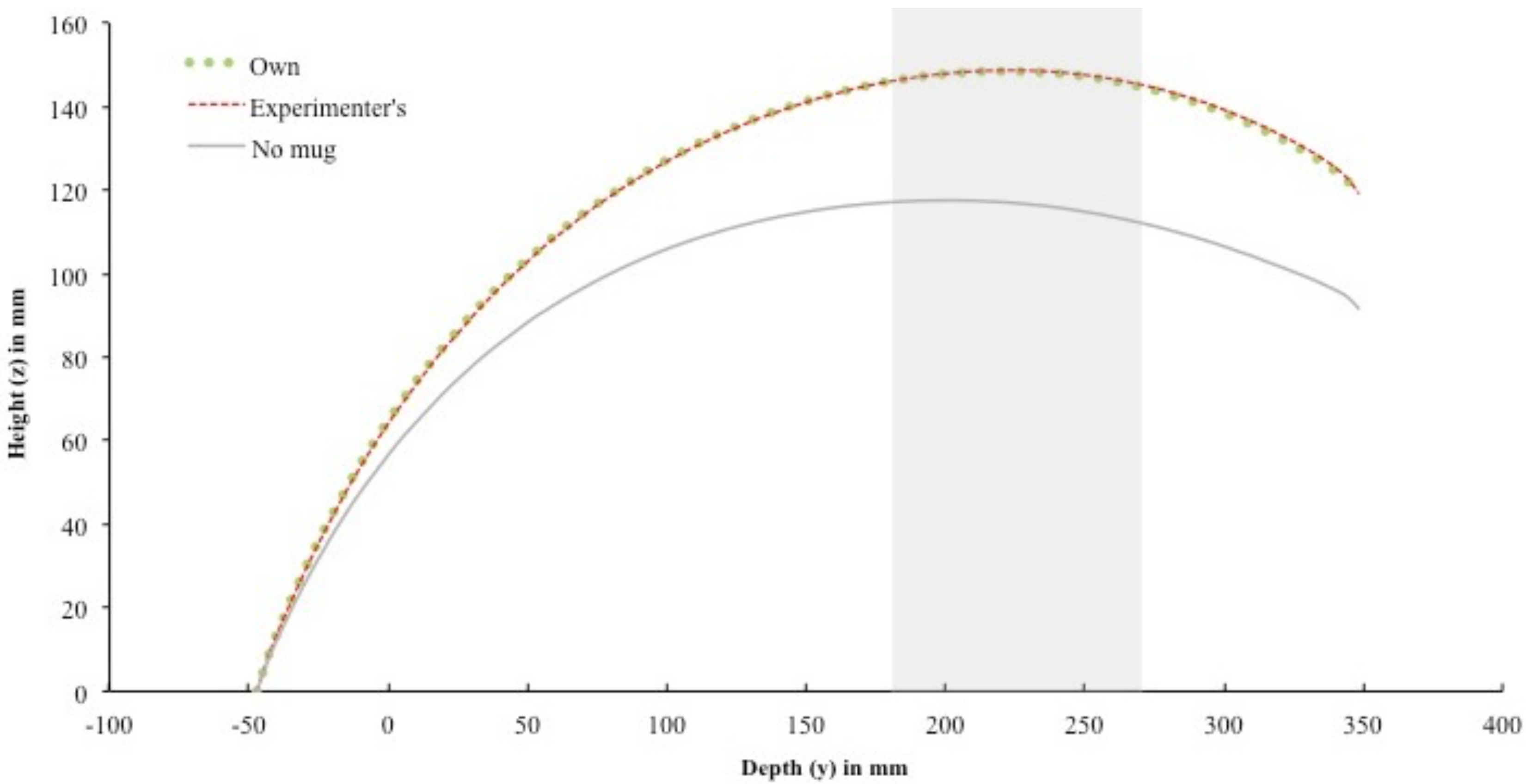

Figure 10. Average trajectories (Z, Y) by condition. Shaded area illustrates depth of obstacles. As anticipated, participants performed lower reaches when no mug obstacle was present compared with trials where their mug and the experimenter's mug were present.

Although not initially anticipated, presuming that participants would adopt a similar grasping position across obstacle and no obstacle conditions due to the instruction to grasp the centre of the cylinder, there was a significant effect of obstacle on Z-deviation at the end point of the movement, F (1.115, 10.035) = 14.319, p = .003, np^2 = .614. Again, planned comparisons revealed that participants' wrist position was lower when no object was present (M = 95.9, SD = 29 mm), compared with reaching in the presence of their own mug (M = 118.4; SD = 12.6; t(9) = 3.633, p = .005), and the experimenters (M = 120.4, SD = 13.2, t(9) = 4.062, p = .003). Again, there was no significant difference in final wrist position when comparing own and experimenter's, t(9) = -1.213, p = .256. Although it is not possible to analyse final target grasping position as a measure of end-point consistency due to the aforementioned index and thumb marker recording issues, the variation in wrist height alludes to the adoption of differing grasping points when obstacles were present, rather than not present. Constraining wrist and arm movement with obstacles does alter the grasping points selected (Voudouris, Smeets, & Brenner, 2012; Alberts, Saling, & Stelmach, 2002), and note that the limb was nearing full extension at the end of the reach, reducing the range of adoptable joint angles. Therefore, it is possible that the mug placement physically constrained the feasible movement paths, which may mask any differences of ownership.

In summary, our initial pilot study did identify deviation, but not movement time, differences between reach-to-grasp movements when reaching over an obstacle, or no obstacle. However, ownership did not appear to interact with this. It is not possible to dismiss that participants' movements were physically constrained by the obstacle, reducing the flexibility to adapt trajectory. The failure to replicate common temporal effects is difficult to account for, especially if the obstacle did physically constrain movements. Therefore, in Experiment 5 we decided to change the owned stimuli for objects of a suitable height for a more traditional obstacle avoidance set-up (Chapman & Goodale, 2008), considering horizontal deviation away from the sides of the obstacles.

Experiment 5

Given the failure to replicate typical obstacle avoidance effects in our pilot study, in Experiment 5 we opted to modify a more traditional obstacle avoidance task (for example, see Chapman & Goodale, 2008) to incorporate obstacle ownership status as a variable. As previous research indicates that shorter obstacles do not produce the same degree of avoidance behaviour in paradigms requiring the participant to reach *between* obstacles (Chapman & Goodale, 2008), and the mugs used in the pilot study are comparatively shorter than the obstacles traditionally used in *'reach-between'* tasks (for example, 25 cm tall cylinders, Chapman & Goodale, 2008), we instead utilised 21 cm tall reusable water bottles as obstacles in this task.

Participants performed reach-to-point movements directed at a target light, moving *between* two obstacles, one owned by the participant, and one belonging to the experimenter (one to the left and one to the right of midline; side of space was counterbalanced). As predicted for the pilot study, we anticipated that a ‘care’ effect would be observed on temporal and spatial measures would occur when the experimenter’s object appeared on the right, as objects on the right produce the largest trajectory effects when using the right hand to respond (Menger et al., 2013).

Method

Participants

Utilising Chapman and Goodale's (2008) N = 20 as an acceptable sample size, informed consent was obtained from 28 participants from the University of East Anglia. All participants were naive to the purpose of the study, and took part in return for course credit or payment. However, motion-tracking data from five participants was corrupted, leaving 23 (M = 23.09, SD = 7.4 years; eight male). Participants were right-handed (Edinburgh Handedness Inventory; Oldfield, 1971), had normal or corrected-to-normal vision, and no history of neurological, or motor disorders.

Apparatus and Stimuli

Participants sat in a dimly lit room at a custom built 1 m × 1 m grey table, with a black start button (button box 32 x 22 mm, button 10 mm diameter) attached centrally to the front edge of the table, and a target red LED 40 cm away from the start button (see Figure 11). Participants wore PLATO LCD goggles to control visual feedback (Translucent Technologies, Toronto, Canada). Six Qualisys Oqus (Sweden) motion-tracking cameras recorded the X, Y, and Z positions of an infrared reflective marker attached to the nail of the right index finger at a sampling frequency of 179 Hz.

Two obstacles, in the form of reusable transparent plastic water bottles (21 cm tall, 6.37 cm diameter at narrowest point, 7.96 cm diameter at widest; see Figure 10), were placed to the left and right of the midline 23 cm away (depth) from the start position. The obstacles (bottles) were identical for the participant and the experimenter, except that the bottle top was either green or yellow according to who owned them. Importantly, the colour of bottle (obstacle) top was counterbalanced between participants (the experimenter always possessed the opposite colour to each participant during testing), so that any effects of ownership could not be simply explained by low-level or familiarity differences between the obstacles.

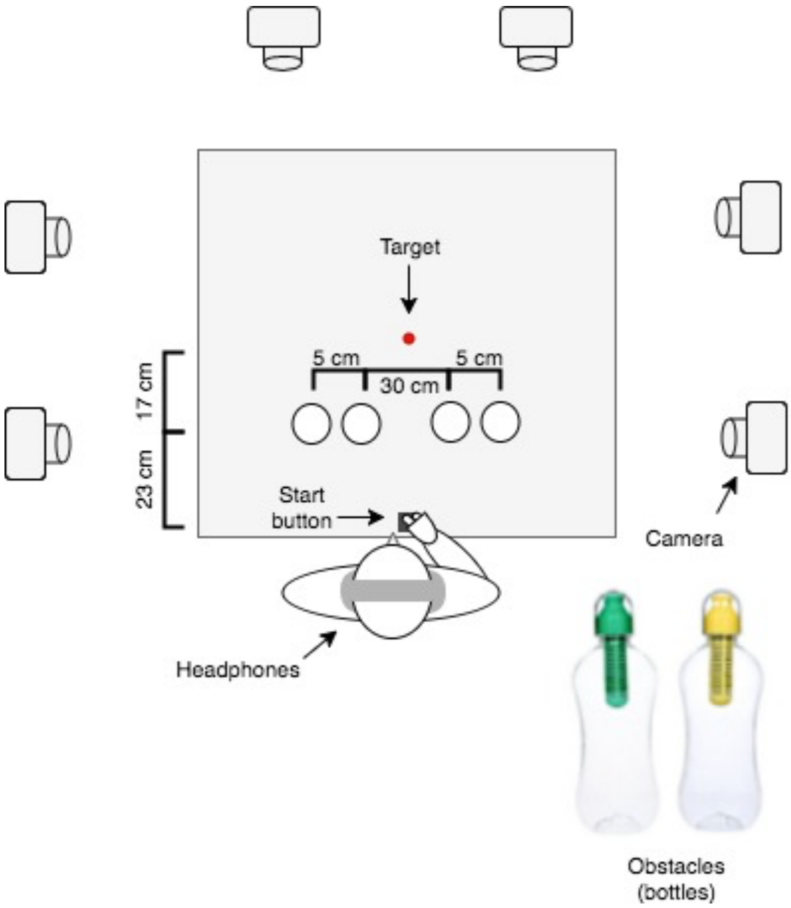

Figure 11. Experiment 5 set up (not to scale). Centre of obstacles (water bottles) were placed 23 cm from edge of table and start button, 17 cm in front of target light. Two obstacles appeared on each trial (one to the left and one to the right of midline, either 15 or 20 cm from midline).

To ensure the experimenter placed the obstacles in the correct configuration for each trial, four LEDs attached to the underside of the table (which were only visible when illuminated) were illuminated in between trials (not visible to participants). To prevent participants from using auditory cues from obstacle placement, plastic furniture buffer pads were attached to the base of each bottle and participants wore noise-cancelling headphones (Quiet Comfort, Bose, USA). A custom designed programme written in Matlab (The MathWorks, USA) was used to control the LED illumination, goggles, auditory cue, and recordings.

Design

In a 2 × 4 within-subjects design, participants performed reaches to the target in the presence of two bottles that differed in ownership status (own and experimenter's). During each trial, each obstacle (own and experimenter's bottle) appeared in one of four locations (15 or 20 cm left or right from table midline), resulting in eight possible configurations (See Figure 1): Own-In - Experimenter-In (the centre of the base at 15 cm from midline), Experimenter-In - Own-In (the centre at 15 cm from midline), Own-Out - Experimenter-Out (the centre at 20 cm from midline), Experimenter-Out - Own-Out (the centre of the object at 20 cm from midline), Own-In - Experimenter-Out (Left 15 cm, Right 20 cm away from midline), Experimenter-In - Own-Out (Left 15 cm, Right 20 cm away from midline), Own-Out - Experimenter-In (Left 20 cm, Right 15 cm away from midline), and Experimenter-Out - Own-In (Left 20 cm, Right 15 cm away from midline; see Figure 12). Own and Experimenter's appeared equally on the right side and left side of space, resulting in eight conditions.

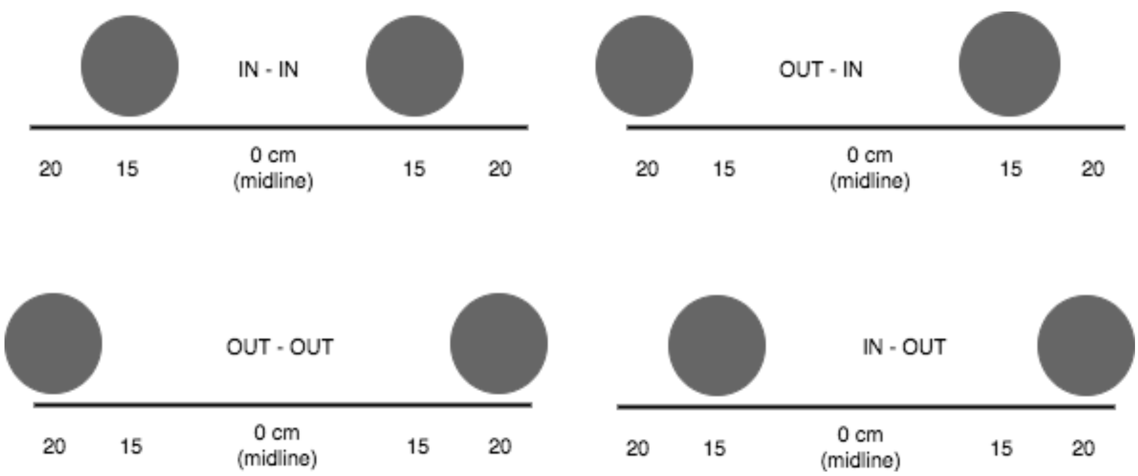

Figure 12. Obstacle configuration conditions for Experiment 5.

The dependent variables recorded were: reaction time (time in ms from auditory go cue to release of start button), movement time (time in ms between start and end of movement), peak velocity (maximum velocity in mm/s during the movement), time to peak velocity (time in ms from start of movement to peak velocity), and X @ 225 (the deviation from midline in mm when the hand passed between the approximate centre of the obstacle depth, Y = 225).

Procedure

Ownership assignment (bottle distribution). Prior to attending the laboratory for the testing session, participants met with the experimenter to receive a water bottle to take away and use for at least three days prior to the experiment (M = 12.14, SD = 4.17 days). Participants were informed that they could keep the bottle (i.e., they owned it), but would need to bring it with them to the testing session and report details of instances when they used the water bottle at the start of the experiment (this manipulation was implemented to encourage use).

Obstacle avoidance task. At the beginning of each trial, participants held down the start button with their right index finger. The PLATO goggles were in opaque configuration, preventing the participating from viewing the experimenter place the obstacles in one of the above configurations by the experimenter. The trial was triggered by the experimenter, who opened the goggles (transparent configuration) for a viewing period of 150 ms, lit the target (red LED), and initiated the motion-tracking recording for 3 s. At the end of the viewing period, an auditory go-signal (beep, 50 Hz, 150 ms duration) was played, cuing the participant to quickly and accurately perform a reach-to-point movement toward the target. Participants were told to ignore any other objects placed on the table, and to focus on the target. However, a viewing period was included in the design to ensure participants attended to the obstacles in order to process their ownership status, before acting. Simultaneously, with button release (i.e., at movement initiation) the goggles returned to opaque configuration, and thus all reaches were performed without visual feedback of the hand, obstacle position, and target (in open loop).

Each participant completed 120 trials, with 15 repetitions for each of the eight obstacle configurations in a pseudo-randomised, one-back controlled order. Before the experiment, participants were given a maximum of 10 practise trials. At the end of the testing session, static recordings of the index at the start position and occluding the target were taken, to allow end-point accuracy calculations.

Data processing. The raw data from the infrared reflective marker was filtered using a low-pass second-order Butterworth filter with a cut-off frequency of 10 Hz, and analysed using customised software written in Matlab. The beginning and end of each reach was defined using a velocity-based criterion of 50 mm/s. A trial-by-trial inspection was carried out to remove any trials in which participants did not complete the task appropriately (such as returning to start position without touching the target, or initiating a reach before the auditory cue), resulting in the exclusion of 61 trials, and one participant, from further analysis. All trajectories were translated so that the first reading of the index finger marker was taken as origin of the trajectory (i.e. 0, 0, 0 in 3D Cartesian space, X = horizontal, *Y* = depth, *Z* = vertical), and were normalised to movement time so they had 100 position measurements, allowing for averaging.

For each trial, the programme extracted the following dependent measures: reaction time (time in ms from go-signal to release of start button), movement time (time in ms between start and of movement as defined by the velocity-based criteria described above), peak velocity (maximum velocity in mm/s during movement time), time to peak velocity (time in ms from start of movement to peak velocity), and the X @ 225 (the horizontal X-deviation in mm when the index finger passed through the obstacles [i.e., 225 mm in depth (Y) from start button]).

Results & Discussion

All dependent measures were calculated for every trial, averaged for each condition (see Table 5), and subjected to a 2 × 4 (ownership × position) within-subjects ANOVA. Where sphericity assumptions were violated, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity. Post-hoc comparisons were Bonferroni corrected. Significant values were set at $p < 0.05$ (two-tailed).

Spatial measures

X@225. For each participant, trajectories were averaged across trials for each condition, before being averaged and plotted per condition across all participants (see Figure 12). As the distance between the obstacle and the index finger was expected to be greatest at around the point the hand passed through the water bottles, the values of X per condition at Y = 225 were subjected to a 4 × 2 ANOVA.

There was a significant main effect of position at Y = 225 [$F(3, 63) = 45.439$, $p < .001$, $\eta p^2 = .684$]. Post-hoc pairwise comparisons revealed that all obstacle configurations produced significantly different X-deviations as the finger passed through the water bottles.

Table 5

Averages by condition (ownership by orientation) for each dependent measure

		Obstacle orientation			
	Object on **right**	In - In	Out - Out	In - Out	Out - In
RT (ms)	Own	372 (100)	371 (92)	377 (97)	376 (99)
	Exp	370 (103)	374 (89)	372.8 (90)	384 (97)
MT (ms)	Own	535 (84)	521 (83)	520 (83)	524 (84)
	Exp	527 (85)	519 (82)	516 (76)	523 (77)
PV (mm/s)	Own	1618 (289)	1647 (281)	1642 (290)	1640 (303)
	Exp	1642 (323)	1656 (299)	1670 (285)	1628 (295)
TPV (ms)	Own	201 (32)	199 (36)	197 (34)	196 (31)
	Exp	203 (36)	199 (33)	198 (31)	203 (35)
X @ 225	Own	-16 (14.6)	-12.11 (14.8)	-9.5 (13.7)	-17.9 (14.9)
	Exp	-16 (14.1)	-12.9 (15.1)	-9.3 (12.9)	-18.4 (14.9)

Note. Standard deviations are displayed in parentheses.

Broadly, these comparisons (see Table 6) revealed participants deviated further away from the right object in the 'In - In' configuration, compared with the 'Out - Out' position. When presented with the 'Out - In' and 'In - Out' configurations, participants moved in the opposite direction, away from, the object placed closest to midline. These deviation differences confirm that a basic obstacle avoidance effect was successfully replicated (for example, see Chapman & Goodale, 2008).

However, contrary to our prediction that greater X-deviation would be observed when the experimenter's obstacle appeared on the right, neither ownership [$F(1, 21) = .565$, p

= .461, ηp^2 = .026], nor configuration × ownership [F (2.016, 42.326) = .619, p = .544, ηp^2 = .029], were significant.

To assess whether our non-significant effect of obstacle ownership was due to a lack of statistical power, we conducted post hoc power analyses using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) with power set at 0.80 and α = 05, two-tailed. This illustrated that to obtain sufficient power (0.80, Cohen, 1988) for the observed effect size (dz = .27, 23% power obtained) for the X-deviation of own vs experimenter's obstacle (right side, averaged over configuration), a sample size of 109 would be required. Thus, the present study was potentially underpowered and we cannot rule out that there was an effect of obstacle ownership to be identified, but the sample size required to detect the effect size observed illustrates its small magnitude.

Table 6

Means and comparisons of X deviation for the main effect of configuration (averaged across ownership). Standard deviations displayed in parentheses.

Configurations	*M* (*SD*) mm	*N*	df	*t*
In - in - out - out	-16 (14.3); -12.5 (14.9)	22	21	-4.209**
In - in - in - out	-16 (14.3); -9.4 (13.3)	22	21	-9.481**
In - in - out - in	-16 (14.3); -18.1 (14.8)	22	21	2.946*
Out - out - in - out	-12.5 (14.9); -9.4 (13.3)	22	21	-3.799**
Out - out - out - in	-12.5 (14.9); -18.1 (14.8)	22	21	7.404**
In - out - out - in	-9.4 (13.3); -18.1 (14.8)	22	21	8.845**

Note. $**p < .01$, $*p < .05$ (Holm-Bonferroni corrected, two-tailed).

A lack of effect of ownership in the present task context was surprising as the plotted averaged trajectories (see Figure 13) are suggestive of potential deviation differences as a function of ownership in the 'Out – Out' condition.

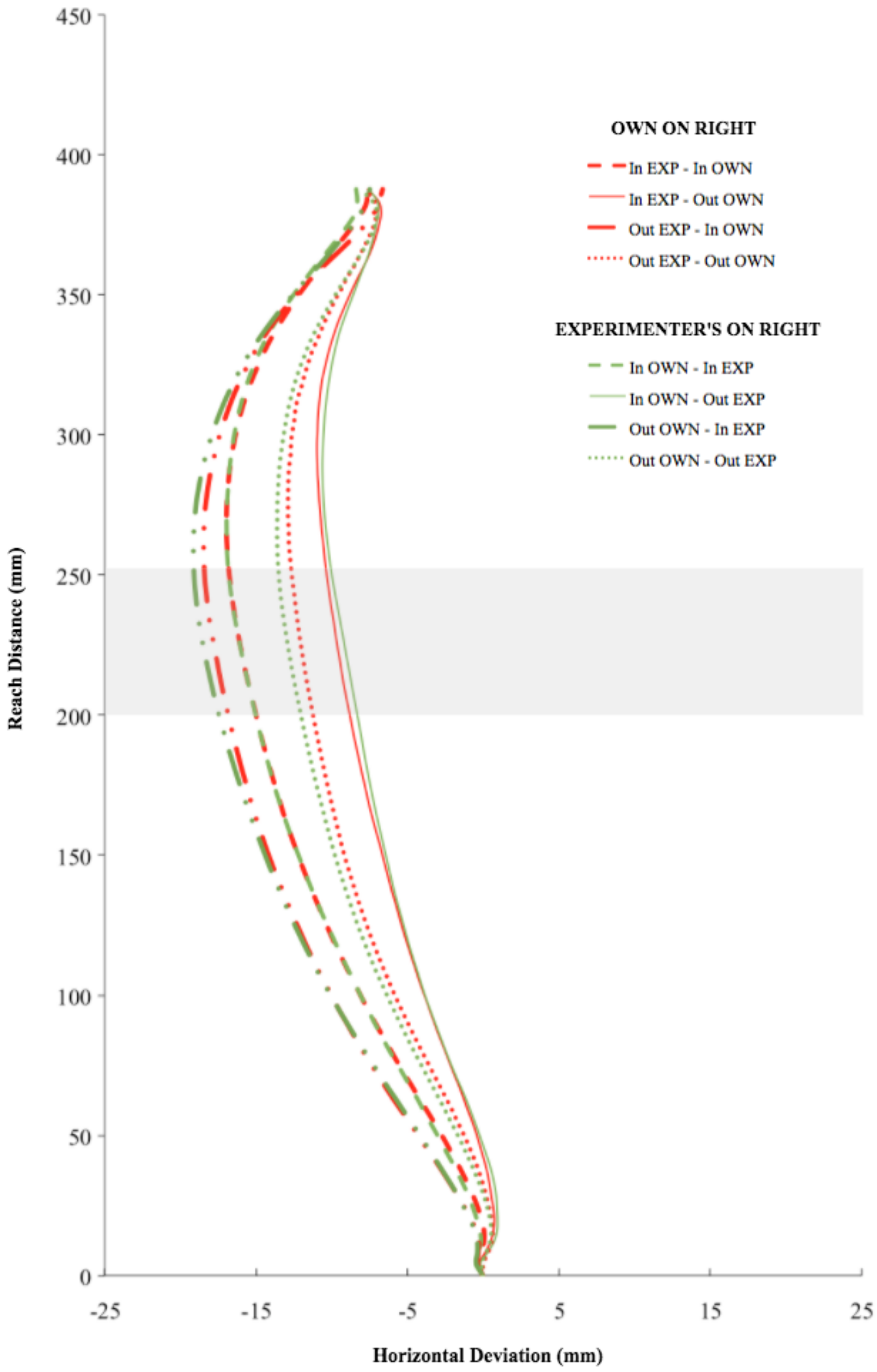

Figure 13. Average trajectories (X, Y) by configuration condition. Shaded area illustrates depth of obstacles.

It is important to note that trajectory deviation differences resulting from identity-related features present in prior studies are subtle. For example, De Haan et al. (2014) only observed a ‘shift’ of 3.3 mm between the averages of passing full and empty water glasses placed on the right. A dual obstacle configuration, as our task used, restricts trajectory deviation compared with only one obstacle appearing to the left or right of midline (Chapman & Goodale, 2010a), especially as participants were already generally deviating more leftward in their movements than typically observed. Although not significant (p = .152, two-tailed), there was a mean deviation of 2.39 mm (SD = 7.37) away from the experimenter's on the right (vs. own) for the condition that allowed the greatest path deviation at Y = 250. Given this, and that previous research reporting identity effects during obstacle avoidance used one obstacle designs (De Haan et al., 2014; Kangur et al., 2017); if ownership does influence obstacle avoidance, a task utilising only one obstacle may better allow subtle ownership effects to be revealed.

Kinematic measures

Reaction time. There were no significant main effects or interactions for reaction time, F (1, 21) < 1.5. However, given that participants were allocated a viewing period and asked to respond upon receiving an auditory cue, no reaction time differences were expected.

Movement time. There was a significant main effect of position on movement time, F (3, 63) = 4.819, p = .004, ηp^2 = .187. Post-hoc tests revealed participants were significantly slower to complete their reaches when the obstacles were positioned in the 'In - In' configuration (M = 531, SD = 84), compared with the 'Out - Out' (M = 520, SD = 82, t(21) = 3.143, p = .03), and 'In - Out' placements (M = 518, SD = 79), t(21) = 3.111, p = .03. There were no significant differences when comparing the other configurations (p > 0.3).

Unlike our initial pilot study, our finding that decreasing the distance between the two obstacles (i.e., the 'In -In' condition, compared with the 'Out - Out', or 'In - Out' condition) increased movement time suggests that our obstacle configuration affected the speed of the movement, mirroring the findings of previous obstacle avoidance studies (for examples, see Chapman & Goodale, 2008; Chapman & Goodale, 2010a, Mon-Williams et al., 2001). Contrary to our prediction, ownership status did not significantly effect movement time; no main effect or interaction was found (ownership: F (1, 21) = 2.185, p = .154, ηp^2 = .094; ownership × position interaction: F(3, 63) = .556, p = .646, ηp^2 = .026).

Peak velocity. We anticipated we would find a significant main effect of position on peak velocity, given that other studies observed reduced peak velocity when reaching between obstacles placed closer to midline and on the right side (Chapman & Goodale, 2008). There was a trend toward a main effect of position; with reduced peak velocity in the 'In - In' (*M* = 1630, *SD* = 304) and 'Out - In' (*M* = 1634, *SD* = 295) condition, compared with the 'In - Out' (*M* = 1656, *SD* = 287) and 'Out - Out' (*M* = 1652, *SD* = 288), but the main effect narrowly failed to reach significance, $F(3, 63) = 2.55$, $p = .064$, $\eta p^2 = .10$. There was no significant main effect of ownership [$F(1, 21) = 1.647$, $p = .213$, $\eta p^2 = .073$] and no significant ownership × position interaction [$F(3, 63) = 1.452$, p = .236, $\eta p^2 = .065$].

Time to peak velocity. In line with Chapman and Goodale (2008), who failed to observe an effect of obstacle position on time to peak velocity; there was no significant main effect of position on time to peak velocity, $F(1.885, 39.581) = .975$, $p = .382$, $\eta p^2 = .044$, and ownership did not interact with position, $F(1.997, 41.933) = 1.271$, $p = .291$, $\eta p^2 = .057$.

However, there was a significant main effect of ownership for time to peak velocity, $F(1,21) = 4.666$, $p = .042$, $\eta p^2 = .182$. Participants took longer to reach peak velocity when the obstacle on the right belonged to the experimenter compared with their own obstacle appearing on the right (*M* = 201, *SD* = 33 vs *M* = 198, *SD* = 32, respectively).

This length of time to peak velocity effect is surprising given that De Haan et al. (2014) observed no effect of object identity on this temporal measure, making our finding difficult to interpret, especially in the absence of other variables influenced by ownership.

In summary, Experiment 5 successfully replicated Chapman and Goodale's (2008) typical obstacle avoidance effects, however, we only found that one kinematic variable was affected by ownership, and no trajectory effects were observed. In previous studies identifying influences of higher-order object features influencing obstacle avoidance, participants completed the reaches under sufficiently different conditions to that of 'traditional' obstacle avoidance tasks. For example, in De Haan et al. (2014), participants performed reaches in closed loop (vision during movement) conditions, with only one obstacle present in the workspace. Completing reaches in the presence of only one obstacle (vs two) is known to elicit greater trajectory deviation (Chapman & Goodale, 2010a). Ownership, and other higher-order features of objects, may become irrelevant to the actor in a context where movements must be navigated to avoid two obstacles, as when reaching between two objects, a movement trajectory is constructed to maintain distance between both objects, centering the hand between the two. It is, therefore, not possible to draw firm conclusions concerning the absence of an influence of ownership from Experiment 5, as two obstacle locations had to be considered when planning movements. In Experiment 6, we decided to adapt the obstacle avoidance design from De Haan et al. (2014), incorporating ownership, rather than water glass content, as our higher-order variable of interest.

Experiment 6

In Experiment 5, we successfully replicated a typical obstacle avoidance effect, with obstacle position mediating movement time and passing distance as the index finger passed by the location of the obstacles. Time to peak velocity did exhibit a main effect of ownership, but this finding is difficult to interpret given that other studies considering the influence of higher-order features on obstacle avoidance have found no influence of identity features on time to peak velocity (see De Haan et al., 2014). However, we failed to observe differences as a result of ownership in our primary variable of interest, X-deviation.

Given that trajectory deviations observed in prior studies are subtle (mean difference, as a function of glass content on right side of space, of 3.3 mm in De Haan et al., 2014), and two obstacle set up's reduce trajectory deviation as a preferred distance is kept between both obstacles (Chapman & Goodale, 2010a), the task may have restricted the opportunity to alter deviation in response to ownership status, as the action system plans to avoid collision with both items, which is arguably more complex than avoiding one object. Practically, there is also only so much deviation one can perform in a reach when flanked by two objects.

In order to reduce the obstacle set up to one item to be avoided, and be better able to draw comparisons about the influence of higher-order features on obstacle avoidance, in Experiment 6, we adapted the task in De Haan et al. (2014), incorporating ownership status as our variable of interest. In addition to obstacle number, this task does differ from Experiment 5 on a number of other features, in order to replicate their task set-up, providing visual feedback throughout the reach, and allowing a longer, jittered viewing period before movement initiation is cued. To allow direct comparison of our obtained results with De Haan et al. (2014), we kept the features of this task (closed loop movement performance) that differed from core features of Experiment 5. Although much of our obstacle avoidance behaviour is assumed to be determined during movement planning, prior to execution (Goodale & Milner, 1992, Milner & Goodale, 2008), we do utilise visual feedback online, when available, to quickly and efficiently perform corrections to movements, for example, in response to 'jumps' in obstacle position (Chapman & Goodale, 2010b). This means that any alteration of the spatial or temporal parameters of movements observed under closed loop (vision available) conditions cannot be as easily attributed to movement preparation processes, as much obstacle avoidance work aims to do.

Therefore, we added an additional open loop (no visual feedback during movement) block after the primary replication block, to compare with the performance in the vision-available condition. If we obtained an avoidance effect in the vision available block (as in De Haan et al., 2014), but not in the open loop (no vision) block, this may be suggestive of an influence of ownership not on the planning of movements, but during movement execution. If we achieved this pattern of findings, it may also be somewhat informative about our failure to observe ownership effects in the previous two experiments, that utilised open loop action performance conditions.

Similarly to Experiment 5, we anticipated that participants would deviate further away from the obstacle owned by the experimenter, compared with their own, when the obstacle appeared on the right side of space.

Method

Participants

Recruiting de Haan et al.'s (2014) N = 17 as a guideline for required sample size, twenty female students (*M* = 19.35, *SD* = 0.79 years) from the University of East Anglia participated in exchange for course credit. However, one participant failed to attend the laboratory for the second session, leaving nineteen. All were right handed, reported having normal or corrected-to-normal vision, and had no history of motor or neurological disorders (Edinburgh Handedness Inventory; Oldfield, 1971).

Stimuli and Apparatus

Participants sat at a 1 m × 1 m grey table. The set up broadly replicated De Haan et al. (2014), with a black start button (button box 32 mm x 22 mm, button 10 mm in diameter) attached centrally 10 cm from the front edge of the table, and a target red LED displayed 40cm away from the centre of the start button (see Figure 14). De Haan et al. (2014) utilised a second button for the reach target, but this set up was not achievable. Participants wore PLATO LCD goggles to control visual feedback (Translucent

Technologies, Toronto, Canada). Six Qualisys Oqus (Sweden) motion-tracking cameras recorded the X, Y, Z positions of an infrared reflective marker attached to the nail of the right index finger and centre of the wrist, at a sampling frequency of 179 Hz.

As in Experiment 5, reusable transparent plastic water bottles (21 cm tall, 7.96 cm diameter at widest point) were used as obstacles, the bottles, one belonging to the participant and one to the experimenter, had either yellow or green mouthpieces, with assigned colour counterbalanced. They were placed to the left or right of midline (8 cm from virtual midline), 22 cm from the start position (see Figure 14).

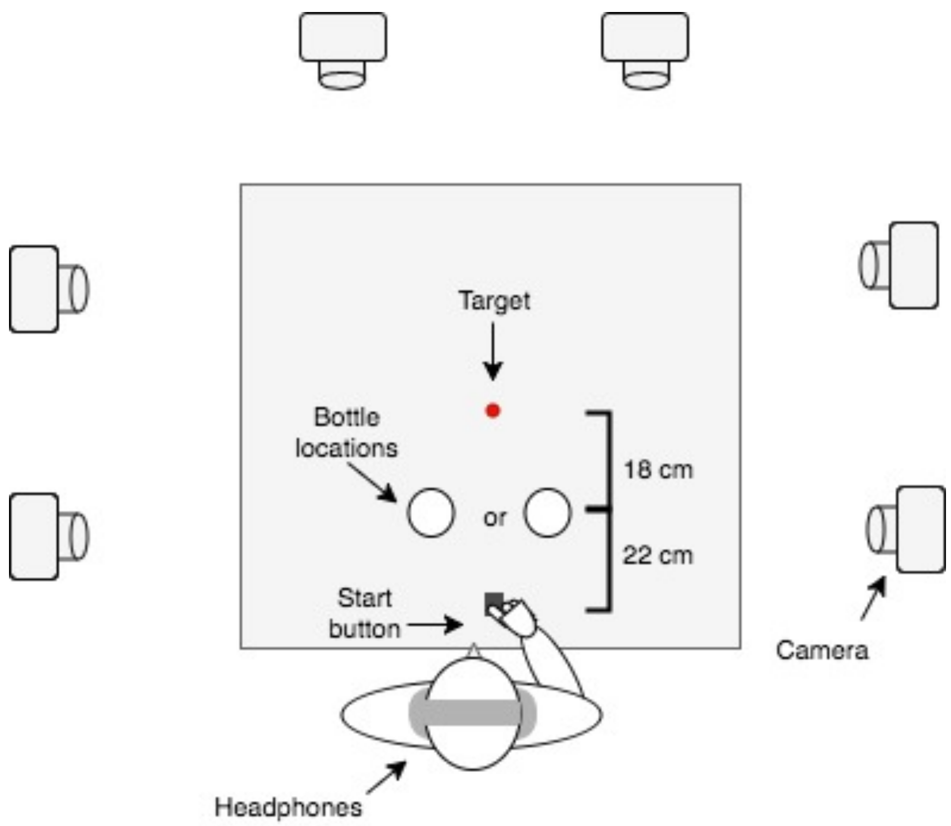

Figure 14. Experimental set-up (not to scale) for Experiment 6. Participants were seated in front of a push button, positioned 10 cm from the front edge of the table. A target light appeared 40 cm from the push button, with an obstacle (when present) appearing 22 cm from the start button, 8 cm to the left or right of midline.

To aid the researcher in placing the obstacles, two LEDs attached to the underside of the table were illuminated in between trials (not visible to participants). To prevent participants using auditory cues from obstacle placement, felt furniture buffer pads were attached to the base of each bottle and participants wore noise-cancelling headphones (Quiet Comfort, Bose, USA). A programme written in Matlab (The MathWorks, USA) controlled LED illumination, the triggering of the goggles, the onset and offset of the auditory go cue and recordings.

Design

A 2 × 2 × 2 within-subjects design manipulated obstacle (own and experimenter's), side (left and right), and vision (vision or no vision). Participants performed reach-to-point movements toward an LED target, with water bottles, belonging to themself or the researcher (or no obstacle), appearing to the left or right of the target. They performed one block of trials with visual feedback available during the reach (closed loop), and a further block with no visual feedback during the reach (open loop, as in Experiment 5). As the closed loop condition was of primary interest, this block was always completed first.

The dependent variables recorded were reaction time (time in ms from the go-signal to release of the start button), movement time (time in ms between start and end of movement, defined by the velocity criterion described above), peak velocity (maximum velocity in mm/s during movement time), time to peak velocity (time in ms from start of movement to peak velocity), and passing distance at y = 220 (the horizontal X-deviation in mm when the index finger passed the centre of the obstacle [i.e., 220 mm in depth (Y) from start button]).

Procedure

Ownership assignment. Prior to attending the laboratory to complete the task, participants received a water bottle to take away and use for at least one week prior to the experiment (M = 13.05, SD = 5.37 days). Participants saw the researcher's water bottle (opposite colour to the bottle assigned to the participant), containing water during this initial session. Participants were told that they could keep the bottle (i.e., they owned it), but would need to bring it with them to the testing session and report details of instances when they used the water bottle at the start of the experiment (this instruction was delivered to encourage use).

Task. Participants were asked to perform quick and accurate reach-to-point movements to occlude a red LED target, appearing on the table. Prior to the task, participants were informed that their own and the researcher's water bottle, would appear on the table during some trials. Participants completed two blocks, one with vision during the execution of the pointing movement, and one without visual feedback. At the beginning of each trial, the participant held down the start button with their right index finger. The PLATO goggles were in opaque configuration preventing the participating from viewing the experimenter place the obstacles. To provide the same inter-trial experience for the participant across all obstacle conditions, both water bottles were placed on the table, before removing one or both.

The trial was triggered by the experimenter, who opened the goggles (transparent configuration) for a viewing period of between 800-1200 ms (randomly generated), activated the target (red LED), and initiated the motion-tracking recording for 3000 ms. At the end of the viewing period, an auditory go-signal (50 Hz, 150 ms duration) was played, cuing the participant to quickly and accurately perform a reach-to-point movement toward the target. In the closed loop condition, upon completing the movement, the researcher manually triggered the PLATO goggles to return to an opaque configuration to set up the next trial.

In the open loop block, simultaneously with button release (i.e., at movement initiation), the goggles returned to opaque configuration, and the reaches were performed without visual feedback of the hand, obstacle, and target. Participants completed 90 trials in total; 45 trials in each block, with 9 repetitions for each of the 5 obstacle configurations in a pseudo-randomised, one-back controlled order. The closed loop (visual feedback available) block was always completed first. Participants completed a maximum of 10 practise trials.

Data processing. The raw data from the infrared reflective markers was filtered using a low-pass second-order Butterworth filter with a cut-off frequency of 10Hz. A trial-by-trial inspection was completed to eliminate trials where participants did not complete the task appropriately, resulting in the exclusion of 29 trials, and one participant, from further analysis. A further participant was excluded due to incorrect starting position resulting in an extreme leftward bias on all reaches. The beginning and end of each reach was defined using velocity-based criterion of 50 mm/s. All trajectories were translated, such that the first reading of the index finger marker was taken as the horizontal (X - width) origin of the trajectory. The true vertical starting coordinate (Y - depth) was maintained. Trajectories were normalised to movement time such that they had 100 position measurements, allowing for averaging.

Results & Discussion

All dependent measures were calculated for every trial and averaged for each condition (see Table 7). A within-subjects 2 × 2 × 2 (vision × side × ownership) ANOVA was conducted for each dependent variable.

Spatial measures

X@220. For illustrative purposes, trajectories were averaged across trials for each condition, along with the baseline no obstacle reaches (see Figure 15). To analyse passing distance, Y = 220 (the depth of the centre of the obstacle) was chosen as the distance from which to extract X-coordinates (horizontal deviation), which were then averaged across trials for each condition.

Table 7

Means by condition for each dependent measure.

		Own		Experimenter's	
Dependent measure	Feedback condition	Left	Right	Left	Right
RT (ms)	Vision	289 (59)	289 (59)	292 (53)	294 (44)
	No vision	335 (97)	316 (85)	312 (94)	326 (72)
MT (ms)	Vision	568 (85)	599 (76)	561 (81)	597 (73)
	No vision	570 (95)	602 (101)	558 (90)	602 (111)
PV (mm/s)	Vision	1483 (235)	1435 (228)	1494 (249)	1428 (224)
	No vision	1505 (353)	1450 (339)	1490 (306)	1437 (330)
TPV (ms)	Vision	192 (34)	203 (43)	188 (41)	202 (41)
	No vision	196 (36)	199 (44)	196 (42)	203 (36)
X@220	Vision	5.6 (3.7)	-30.6 (11.8)	5.2 (5.3)	-30 (13.2)
	No vision	2.2 (9.5)	-29.6 (10.6)	4 (8.9)	-31.1 (12.5)

Note. RT (reaction time), MT (movement time), PV (peak velocity), TPV (time to peak velocity), X@220 (horizontal deviation at y = 220).

As anticipated, given findings from Experiment 5 and other obstacle avoidance work

(Chapman & Goodale, 2008, De Haan et al., 2014), there was a significant main effect of side, $F(1, 16) = 135.08$, $p < .001$, $\eta p^2 = .894$. Participants deviated more when the obstacle appeared to the right of midline ($M = -30.3$, $SD = 11.1$ mm), compared with the left ($M = 4.3$, $SD = 5.7$ mm). Contrary to our prediction that participants would deviate more when the experimenter's bottle appeared on the right side of space, both with and without vision, the ownership × side interaction was not significant, $F(1, 16) = 2.796$, $p = .114$, $\eta p^2 = .149$. The main effects of vision and ownership [$F(1, 16) > 1$], vision by side, and vision by ownership, [$F(1, 16) > 3$] were not significant. However, the three-way interaction narrowly missed significance, $F(1, 16) = 4.184$, $p = .058$, $\eta p^2 = .207$. To investigate this trend, a two-way ANOVA was conducted for each block (vision and no vision).

Closed loop (with visual feedback). There was a significant main effect of side, $F(1, 16) = 124.337$ $p < .001$, $\eta p^2 = .886$, but not of ownership [$F(1, 16) = .043$, $p = .838$, $\eta p^2 = .003$], and no significant interaction [$F(1, 16) = .495$, $p = .492$, $\eta p^2 = .03$]. In line with Experiment 5, participants deviated more in response to an obstacle appearing on the right ($M = -30.3$, $SD = 12$ mm), compared with reaching in the presence of an obstacle on the left ($M = 5.4$, $SD = 4.1$ mm). However, contrary to our predictions based on findings that greater physical consequences of collision influence movement deviation when visual feedback is available (De Haan et al., 2014), ownership did not mediate deviation under such conditions.

Open loop (without feedback). Again, a significant main effect of side was observed, $F(1, 16) = 7.421$, $p = .015$, $\eta p^2 = .317$, with average X-deviation away from the obstacle greater when it appeared on the right; and the main effect of ownership was not significant [$F(1, 16) = .132$, $p = .721$, $\eta p^2 = .008$].

In contrast to the closed loop block, there was a significant ownership × side interaction [$F(1, 16) = 6119.609$, $p < .001$, $\eta p^2 = .882$. Planned comparisons indicated that when reaching in the presence of an obstacle, participants deviated further away from the experimenter's obstacle, compared with their own, but only when placed on the left, $t(16) = -3.088$, $p = .007$ (two-tailed). There was no significant difference between deviation when the experimenter's or participant's own was placed on the right, $t(16) = 1.43$, $p = .172$ (two-tailed).

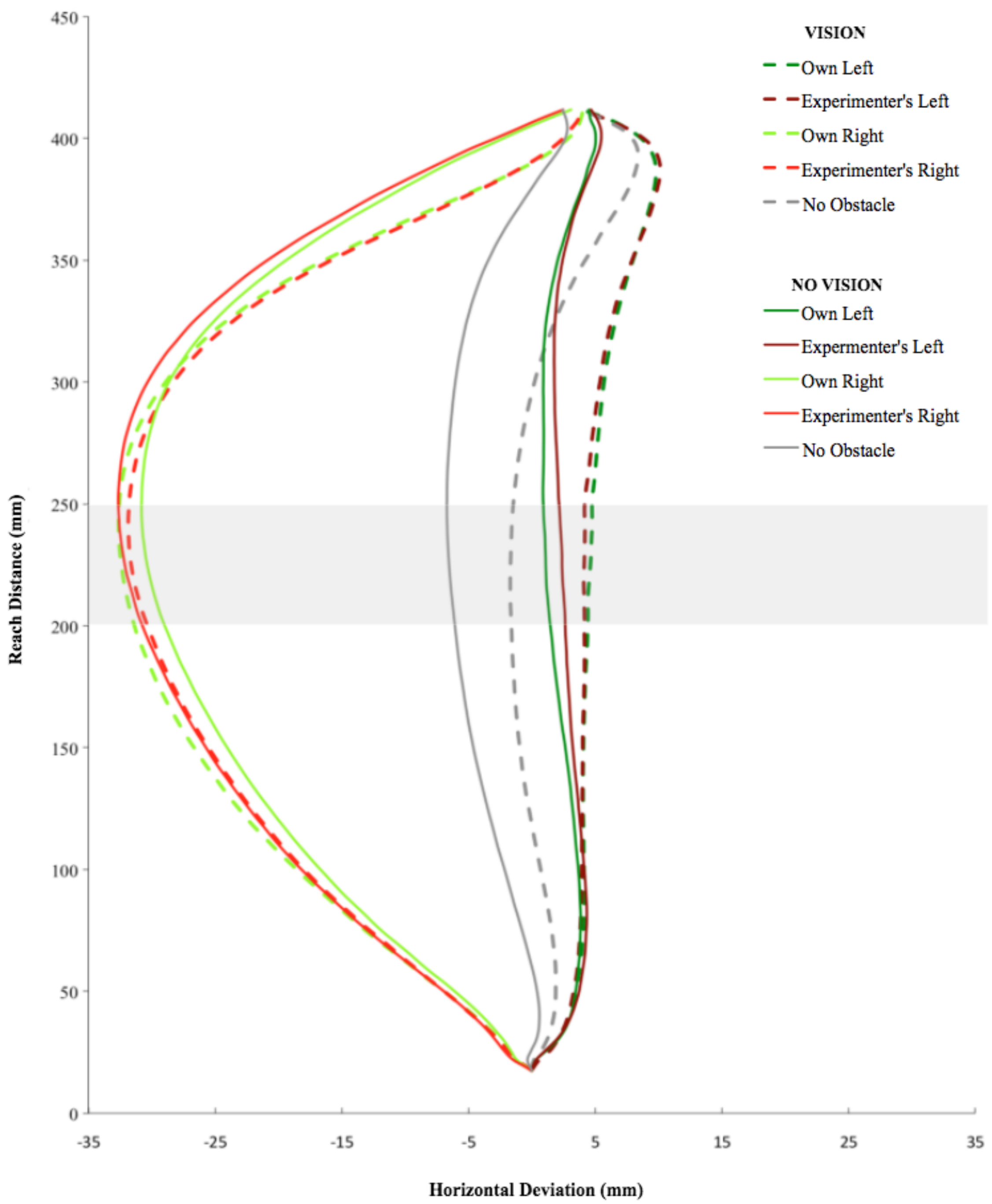

Figure 15. Average trajectories (X, Y) by condition (own or experimenter's obstacle when appearing to the left and right of midline), for visual feedback and no visual feedback. Shaded area illustrates depth of obstacles.

Participants in De Haan et al. (2014) only performed movements under closed loop (visual feedback conditions), and an effect of identity on passing distance was only observed when the glass appeared on the right. Therefore, when considering the lack of an effect of ownership on X-deviation in the visual feedback block, it is surprising that we failed to observe an effect of ownership. It is unlikely that practice or carryover effects are responsible for introducing this ownership effect in the no vision block, as a difference in only certain conditions emerged, rather than generically across reaches. However, counterbalancing block order or reversing block order would be worthy of attention in a follow-up study. We elected not to counterbalance in the current study to more easily compare findings from De Haan et al. (2014) with our results.

Temporal measures

Reaction time. There was a significant main effect of vision, $F(1, 16) = 7.868$, $p = .013$, $\eta p^2 = .330$. Participants took longer to respond after the tone in the no vision condition ($M = 322$, $SD = 76$), compared with vision ($M = 291$, $SD = 49$). No other main effects or interactions were significant [$F(1, 16) > 1$]. Reaction time differences were not expected as participants received a viewing period of 800-1200 ms before being cued to respond to perform a simple movement. The slightly longer response time in the no vision block was likely due to movement planning prior to initiation, given that online control would be restricted when visual feedback was removed.

Movement time. Unlike reaction time, there was no significant main effect of vision on movement time, F(1, 16) < .1. However, there was a significant main effect of side of space, $F(1, 16) = 29.985$, $p < .001$, $\eta p^2 = .652$. Movements were slower when the obstacle appeared on the right ($M = 600$, $SD = 82$ ms), compared with left ($M = 554$, $SD = 20$ ms). The main effect of ownership narrowly missed significance, $F(1, 16) = 4.103$, $p = .06$, $\eta p^2 = .204$, but was superseded by a significant 2-way ownership by side interaction, $F(1, 16) = 6.618$, $p = .02$, $\eta p^2 = .293$.

Simple main effects analysis indicated that average movement time was slower than when their own object appeared on the left ($M = 569$, $SD = 85$), compared with the experimenter's on the left ($M = 559$, $SD = 81$), $t(16) = 3.017$, $p = .016$ (two-tailed, Holm-Bonferroni corrected). There was no significant difference for ownership on the right side of space, $t(16) = .226$, $p = .412$. The two-way interactions vision × side and vision × ownership, and the 3-way vision × side × ownership, were not significant [$F(1, 16) < .5$].

Peak velocity and time to peak velocity. Contrary to De Haan et al. (2014), who found no effect of position on peak velocity, a significant main effect of side was observed in both the closed loop and open loop conditions, $F(1, 16) = 10.985$, $p = .004$,

$\eta p^2 = .407$. Participants achieved greater peak velocity when the obstacle appeared on the left (*M* =1493, *SD* = 265 mm/s) compared with the right (*M* = 1438, *SD* = 253 mm/s).

However, there was no significant main effect of vision or ownership, and no significant interactions [$F(1, 16) < 1.5$]. Similarly, there was a main effect of side for time to peak velocity [$F(1, 16) = 6.086$, $p = .025$, $\eta p^2 = .276$]. Participants took longer to achieve peak velocity when the obstacle appeared on the right side (*M* = 206*, SD* = 33) vs left (*M* = 197, *SD* = 32). All other main effects and interactions were non-significant [$F(1, 16) > 2$].

Given that other studies have observed reduced peak velocity and increased movement time when reaching between obstacles placed closer to midline and on the right side, this effect is not surprising (for example, see Chapman & Goodale, 2008). It is possible that the irregular shape of the water bottles used as obstacles in our task may have been more obstructing, and therefore movements were planned and executed with more caution (regardless of identity), than movements produced in the presence of the cylindrical glasses De Haan et al. (2014) adopted as obstacles. The average X-deviation observed for the obstacle placed on the right side of space, was slightly larger in our study than the passing distance they observed, also eluding to the possibility that our obstacles may have been more 'obstructing'. However, in general, the core obstacle avoidance effect observed is consistent with that reported by De Haan et al. (2014), and the rest of the literature (for example, see Chapman & Goodale, 2008, Chapman & Goodale, 2010a).

General discussion

The purpose of the experiments presented in this chapter was to extend findings concerning the effects of ownership status on action beyond the context of object-directed movement (see Constable et al., 2011, 2014, 2016), investigating whether higher-order knowledge of ownership status influences movement kinematics when self and experimenter-owned objects are obstacles, rather than targets. Obstacle avoidance is assumed to be predominantly underpinned by the dorsal stream (Goodale & Milner, 1992, Milner & Goodale, 2008), but there is evidence to suggest features of objects processed outside the realm of the dorsal network do influence obstacle avoidance (De Haan et al., 2014, Kangur et al. 2017). Ownership represents another such feature, but had yet to be investigated. Broadly, Experiment 6 found that ownership status appears to be another non-spatial identity-related feature that can influence obstacle avoidance. However, the lack of effect observed in Experiment 5, and subtleties of the results in Experiment 6, suggests that this only occurs under certain conditions.

In the pilot study, we initially trialed a task set-up less normatively adopted in order to investigate obstacle avoidance; requiring participants to reach over obstacles of differing ownership status. Rather than initially recruiting a more normative obstacle avoidance task, this design was piloted in order to allow the recruitment of owned objects that have yielded action-related ownership effects in both our own, and others, studies of motor control; coffee mugs. Given findings that shorter obstacles exert less influence on horizontal deviation of movements in general (Chapman & Goodale, 2008), we attempted to replicate a general avoidance effect in a task requiring participants to reach over obstacles. However, this design failed to elicit typical obstacle avoidance findings, regardless of ownership status. Given that this task set-up did not produce typical obstacle avoidance behaviour, in Experiment 5, we adapted a traditional obstacle avoidance task (Chapman & Goodale, 2008), utilising reusable water bottles as obstacles of differing ownership status (own or experimenter's). After a short preview period, participants performed reaches toward a target light, reaching between two obstacles. They had no visual feedback of obstacle position, hand, or target once they had commenced their movement. In accordance with previous research (Biegstraaten et al., 2003, Chapman & Goodale, 2008, Chapman & Goodale, 2010a, Menger et al., 2013, Mon-Williams & McIntosh, 2000, Mon-Williams et al., 2001, Tipper et al., 1997, Tresilian, 1998), we successfully replicated a traditional obstacle avoidance effect with this task; with more deviation away from the object on the right side of space when it was closer to the participant, and slower movements under these conditions.

In establishing whether ownership status mediated avoidance behaviour, we were most interested in the X-deviation measure at the point the index finger passed the obstacles. However, no differences in deviation as a function of ownership were observed in Experiment 5. A main effect of ownership status on time to peak velocity was observed, with participants taking longer to reach peak velocity when the object on the right belonged to the experimenter (vs. own on right). However, this effect is difficult to interpret as previous research has not identified any influence of identity-related features on time to peak velocity (De Haan et al., 2014, Kangur et al., 2017), and it failed to replicate in Experiment 6. Although note, as outlined previously, the set up of our task made drawing comparisons between other research investigating identity-related features and Experiment 5 difficult. To ensure that the dual obstacle configuration adopted, which restricts the potential for limb deviation, was not limiting possible ownership effects (due to, arguably, increased movement complexity), in Experiment 6, we chose to adapt the task from De Haan et al. (2014), substituting water glass content for ownership status. The recruitment of this task also facilitated direct comparison of results with their finding that obstacle identity mediated avoidance behaviour.

In Experiment 6, participants again performed reaches toward a target light. However, only one obstacle was presented to the left or right of midline, and the viewing period before the auditory go-signal was significantly extended. Participants also completed one block with visual feedback of the obstacle, hand, and target, but an open loop (no vision) block was also conducted subsequent to the closed loop block.

In line with Experiment 5 and the obstacle avoidance literature, we again successfully replicated a typical obstacle avoidance response. When the obstacle appeared on the right, compared with the left, movement time was increased, peak velocity was reduced, and movements veered away from the obstacle to a greater degree. Unlike Experiment 5, in addition to observing typical obstacle avoidance behaviour, there was some evidence that ownership status also influenced movement deviation, with participants veering further away from the obstacle when it belonged to the experimenter, compared with the ‘self-owned’ obstacle. However, this effect was only observed in the no vision (open loop) block, and contrary to what we anticipated, this effect was only significant for obstacle placement on the left side of space. Participants in De Haan et al. (2014) only performed movements under closed loop (visual feedback conditions), and an effect of identity on passing distance was only observed when the glass appeared on the right. Therefore, our pattern of effects, namely a lack of effect in the visual feedback block, and presence of an effect when the experimenter’s appeared on the left during the open loop block, initially appears irregular when contrasted with that of De Haan and colleagues.

It is assumed that the influence of higher order features of obstacles on avoidance responses is due to the consequences of collision associated with those features. The consequences of collision in De Haan et al. (2014) were physical (and potentially dangerous!); knocking over a full glass of water may be a more salient and worrisome consequence than the faux pas of colliding with someone’s item (that is not breakable). In Experiment 6, the salience of ownership, and the associated consequences of colliding with an object belonging to another person, may only be sufficiently salient in order to influence trajectory when no online control is available. This may beg the question as to why we failed to observe ownership-related effects in the open loop task set-up in Experiment 5. However, the obstacle set-up within Experiment 6 saw the obstacles placed closer to midline than the positioning adopted in Experiment 5, increasing the possibility of collision (and therefore requiring greater care) than Experiment 5, while removing the second obstacle allowed greater deviation.

Although much of our obstacle avoidance behaviour is assumed to be determined during movement planning, prior to execution (Goodale & Milner, 1992, Milner & Goodale, 2008), when available, we do utilise visual feedback online (Chapman & Goodale, 2010b). Therefore, the lack of ability to perform online corrections to avoid collision, especially after completing the task with visual feedback, may have made participants more sensitive to ownership and the costs of knocking over the experimenter's object, resulting in a greater deviation away from the obstacle owned by the experimenter. Removal of vision may be the further 'boost' needed to increase the salience of the ramifications of collision under our task conditions. In future studies, further increasing the consequences of collision by using more fragile objects, or those with greater sentimental value, may strengthen the avoidance response observed in our study, and render the effect observable under visual feedback conditions.

The finding that under no vision conditions, ownership status only influenced X-deviation when the object appeared on the left is also contrary to what we anticipated, based on previous work that only found an effect of identity when the obstacle appeared on the right (De Haan et al., 2014). However, it is worth noting that the difference between X-deviation when comparing own and experimenter's obstacle on the right is similar to the significant difference in deviation as a function of ownership for the left side of space, but there was greater variance for the right side of space condition, compared with the left. Why movements varied more in response to the right obstacle is somewhat unclear. It is possible that inconsistent starting posture caused more variance in the movements produced when the obstacle appeared on the right hand side. There is evidence that wrist position (when the wrist is placed slightly diagonally across the table with the elbow protruding to the right; compared with the wrist placed in line with the trunk, behind the index finger) influences horizontal deviation during obstacle avoidance. Further supportive of the possibility that inconsistencies in wrist position could introduced greater variance in X-deviation for right sided obstacles only, wrist position was found to more greatly affect deviation for ipsilateral than contralateral obstacles (Menger, Van der Stigchel, & Dijkerman, 2012). Attempts were made to ensure participants adopted an appropriate, and consistent, wrist position. However, future research should endeavour to ensure consistent wrist position to avoid additional movement variance. The X-deviation differences observed as a function of identity in studies like De Haan et al. (2014) are small. Therefore, it is imperative that variance as a result of other factors is reduced.

In addition, it is worth noting that Experiment 6 may have suffered from an underpowered design, reducing the capability to detect spatial deviation effects in some conditions. Post-hoc power analysis indicated that we only had 27% power to detect the effect size obtained (dz = .345) for X-deviation when comparing Own and Experimenter's on the right. Therefore, as the obtained power fell below the recommended 80% (Cohen, 1988), we cannot rule out the possibility of detecting a significant effect in X-deviation to objects when on the right if our design possessed greater power. Based on this, increasing sample size would also be beneficial in future research.

To conclude, this chapter aimed to investigate whether top-down knowledge of ownership status influences obstacle avoidance. To date, the limited research considering the effects of ownership status on action has focused on the execution of movements performed on objects of differing ownership status, establishing that we take more care when interacting with others’ possessions. However, we also move within environments cluttered with others’ belongings. How we navigate movements in the presence of objects belonging to others is of equal interest ecologically. In Experiment 6, we observed that ownership status could influence the movement paths executed when reaching for a target in the presence of own or experimenter-owned obstacles. However, this effect is subtle and potentially limited only to certain conditions. Methodological considerations, such as the counterbalancing of block order and consistency in the start position of the wrist need to be addressed in follow up research. As the influence of object features on avoidance is assumed to only impact due to differing consequences of collision, future research could aim to increase the salience of the consequences of colliding with property belonging to another, for example, by using breakable possessions, to establish whether this further elucidates the subtle trajectory effects observed.

Chapter 5. Discussion

Reminder of thesis purposes

While many disciplines have long considered the origins, functions, and consequences of ownership, there has been a historical absence of work considering the cognitive basis of ownership. Interest in the cognitive processing biases afforded to personal property is growing, with publications proliferating during the production of the present thesis. A plethora of findings indicate that objects associated with the self (vs. those associated with another) receive enhanced processing at early stages of object discrimination (Sui et al., 2012), are afforded prioritised attentional selection (Truong et al., 2016, Yanouskaya et al., 2016), extended a greater degree of attentional processing (Turk et al., 2011), and are advantageously encoded, and subsequently better recalled (Cunningham et al., 2010, Van den Bos et al., 20102). However, research addressing how ownership status affects the motor system remains relatively underdeveloped.

As the concept of ownership is partly comprised of permission to interact with our own objects, and deny others such use without permission (Snare, 1972), it may represent another abstract concept that exerts embodied effects on the motor system. Constable and colleagues (2011, 2014, 2016) have provided initial evidence that the visuomotor system is sensitive to the ownership status of objects, and that beyond facilitation for self-objects, knowledge of other-ownership is also pertinent to the nature of planned and executed responses. Therefore, embodied ownership effects warrant further investigation, and the present thesis aimed to extend evidence for such motor effects. Importantly, we were interested in the possible effects of ownership status for self-owned *and* other-owned objects, as aside from Constable's work, focus remains on the facilitated processing of self-associated objects.

This chapter will initially summarise key findings from the present experiments, situating them in the context of previous work on both self and other-ownership biases. Based on the offered synthesis of our and others' findings concerning ownership, I will discuss future theoretical directions, and the potential applications of a growing body of knowledge concerning the cognitive treatment of ownership. Finally, methodological challenges experienced during attempts to establish the effects of ownership on the motor system via indirect methods, such as response time, will be outlined; before proposing a viable technique for more directly studying motoric effects (which we aimed to implement, but were constrained in achieving this by equipment limitations).

Summary and evaluation of findings

Aiming to directly extend on previous movement kinematics work that is suggestive of the elicitation of affective compatibility effects as a function of ownership (Constable et al., 2011, 2014), the experiments presented in Chapter 2 utilised a touchscreen version of an Approach-Avoidance Task (Bamford & Ward, 2008), progressively developed across the three experiments. Participants performed approach or avoidance movements to categorise self-owned and other-owned (experimenter's, unknown other and unowned in Experiment 1 & 2, unknown other in Experiment 3) coffee mugs. Broadly in line with our predictions and previous indirect evidence, participants were significantly faster to approach the mug belonging to themselves, and faster to avoid the mug belonging to an unknown other (vs. approach).

However, such effects were limited by task context. For example, affective compatibility effects only emerged when ownership was rendered explicit by task demands to categorise objects based on ownership. Even under task-relevant conditions, other-ownership effects were subtler, and mediated by the probability of ownership category (self and other). When participants only responded to self and unknown other mugs (vs. own, experimenter's, another's, and unowned), the facilitation of avoidance time for the unknown other's mug dissipated.

While the work presented in Chapter 2 aimed to extend findings concerning motor effects, the adopted task design inherently confounded alternative explanations of facilitated approach (vs. avoidance time) for self-owned property, such as attention capture, which is known to be mediated by self-relevance in general (e.g., Alexopoulos et al., 2012, Bredart et al., 2006, Mack & Rock, 1998, Shi et al., 2011), and self-ownership in particular (e.g., Turk et al., 2011, Yanouskaya et al., 2016). Therefore, Experiment 4 aimed to eliminate the requirement for attentional shifts to produce avoidance movements. This could have been achieved by adopting a number of alternative computerised paradigms, for example, through the recruitment of a joystick-based task (Chen & Bargh, 1999). However, given that both our own, and others' (Constable et al., 2014), experimental work alludes to the greater influence of design and contextual factors on other-ownership conditions, we wished to recruit a task that was potentially more ecologically relevant than computer-based paradigms.

Therefore, Chapter 3 returned to the use (see Constable et al., 2011, 2014, 2016) of motion kinematics, as a means of recording real motor responses while interacting with objects of differing ownership status. Participants categorised the self-owned and experimenter-owned mug on the basis of ownership, by pushing the mug away from the torso, or bringing it toward the self. Consistent with findings from the computerised AAT, but more adequately controlling for attentional confounds, participants were faster to initiate approach movements for self-owned relative to for experimenter-owned property. However, despite a context that, arguably, increases the salience of other-ownership as an object property; there was no difference in the initiation of avoidance when responding to the experimenter's or self-owned mug. However, note that limited statistical power may have played a role in limiting the significance of some of the statistical comparisons conducted.

Based on findings (dissociable from indirect trajectory deviations that allude to affective compatibility; Constable et al., 2014) that participants take greater care with objects belonging to another (vs. self and unowned) during interactions with the object, indexed by reduced peak acceleration during lifting (Constable et al., 2011, 2014), Chapter 4 aimed to expand knowledge of motoric ownership effects beyond its influence on object-directed action to another action context that, to the best of my knowledge, has yet to be investigated. Given there is a 'care' effect when interacting *with* others' belongings, movements in the presence of another's property while reaching for a target object may be equally mediated by ownership. Recent findings that increasing the physical consequences of collision (empty vs. full water glass) mediated avoidance reach trajectory, with greater distance maintained between the limb and the obstacle (De Haan et al., 2014), further supported this notion. Therefore, this chapter explored whether the ownership status of obstacles within the environment mediates the temporal and spatial parameters of reaching movements (directed toward a target). Participants performed reaches in the presence of an object owned by themselves or the experimenter, while reaching for a target object.

Broadly, we found evidence of mediation of obstacle avoidance as a function of ownership, with subtle differences in trajectory deviation (away from the experimenter's obstacle) observed in Experiment 6. However, this effect was not observed when reaching in the presence of two obstacles (self and experimenter's, Experiment 5). Given that movements between two obstacles are executed in a manner maintaining a minimum preferred distance between *both* objects (Tresilian, 1998, Chapman & Goodale, 2008), it appears that ownership only possesses relevance for obstacle avoidance movement plans when there is no cost associated (such as colliding with the other object) with taking greater care to avoid the experimenter's property. Alongside revealing other-ownership effects in a new context, Chapter 4 also contributes to the, still largely uninvestigated, influence of non-dorsal stream object properties on obstacle avoidance; suggesting that identity-related features of objects can influence avoidance behaviour.

In summary, across Experiments 1, 3 and 4, self-property consistently received enhanced motoric responses in contexts where ownership status was task-relevant, with response time illustrating a tendency to approach self-owned objects faster than property belonging to another. Such a finding extends the rapidly growing body of literature that has identified numerous processing biases for objects associated with the self, namely, mnemonic advantages (Cunningham et al., 2008, 2013, van den Bos et al., 2010), attentional prioritisation (Turk et al., 2011, Truong et al., 2016, Yanouskaya et al., 2016) and facilitated stimulus discrimination (Schäfer et al., 2015, Sui et al., 2012; 2013, Sui & Humphreys 2015a); by demonstrating that self-owned objects also facilitate the execution of congruent (approach) motor responses. However, the failure to observe affective compatibility effects for self-owned objects when asked to make a judgment based on an object feature, such as mug handle colour (rendering ownership irrelevant to the task), bolsters a notion that self-ownership does not possess *absolute* salience during stimulus processing and response preparation (for similar findings in perceptual matching tasks, see Liu & Sui, 2016; Stein, Siebold, & van Zoest, 2016).

Note that in the interests of replication of previous embodied ownership work and the preservation of ecological validity (particularly for investigation of other-ownership effects), we initially opted not to control for other object characteristics that are inherently confounded with ownership occurring in normative settings, such as choice, and familiarity. Therefore, we do note that we cannot exclude that such characteristics may be accountable for the effects observed. Given that affective compatibility effects theoretically arise from stimulus valence, factors such as choice, which influence stimulus evaluation (Huang et al., 2009) are also likely to elicit similar effects (see Constable et al., 2014). Therefore, there is clearly future need to investigate affective compatibility effects for *self*-owned property in the absence of contaminating variables.

Additionally, neural evidence alludes to overlap in the mechanisms of self and reward/affective processing (Enzi et al., 2009; Phan et al., 2004). While self-object processing biases do not appear to result *solely* from the rewarding or affective nature of the stimulus (for example, see Sui et al., 2015; Sui & Humphreys, 2015b; Sui & Humphreys, 2015c); the precise nature of the relationship is not yet clear. Given the findings concerning congruency effects for self-owned property presented within this thesis, and their theoretical basis in differences in stimulus affect (see Niedenthal et al., 2005), it will be fruitful to continue to elucidate the manner in which, and extent that, ownership representations are underpinned by valence or reward-based components.

However, the elicitation of subtle other-ownership effects, which are less easily accounted for by factors such as choice or familiarity does lend support to the accessibility of the construct of ownership during action planning (Experiment 1, 2 & 6; Nevertheless, future research should endeavor to explore affective compatibility effects in the absence of such confounds). Specifically, our findings that property belonging to another can facilitate avoidance motor performance and affect movement execution when property is not the subject of object-directed action, but an obstacle during action performance, broadly supports, and further extends, the work of Constable et al. (2011, 2014, 2016), who observed that lifting and passing actions are mediated by other-ownership (alongside self-ownership).

The work of Constable and colleagues was the first to demonstrate visuomotor effects for *both* other and self-owned property, illustrating that while self-ownership is an important ‘category’ of stimuli eliciting embodied motor effects, the action system is not blind to the importance of other-ownership. Similarly, the present thesis also situates other-ownership as a category of interest in itself, rather than as a social but less salient comparison group (for self-owned). More broadly, considering the visuomotor effects of ownership also extends evidence that more abstract, sociocultural concepts, that cannot be directly perceived (and therefore seemingly cannot be represented with perceptual experiences), do appear to be associated with embodied sensorimotor states, influencing subsequent responses (for investigation of the embodied nature of the abstract concept of morality, see Schnall, Benton & Harvey, 2008; Lee & Schwarz, 2010).

However, perhaps the most significant contribution the present thesis makes to the investigation of the embodiment of an abstract concept, such as ownership, is the identification of the difficulty in observing, and *consistently* eliciting, effects. Some existing findings do reflect the criticality of task context in the elicitation of embodied other-ownership effects. For example, Constable et al. (2016) found that when passing a mug (owned by the passer or the receiver) to another individual, the difference in the orienting of the handle in order to facilitate the receiver's grasp only reached significance in a condition where the receiver was to act upon the object. Similarly, findings pertaining to the influence of other-ownership within the present thesis were subtle and appeared to be contextually mediated. As discussed, the elicitation of affective compatibility effects for property belonging to an unknown other (Chapter 2) seemed to depend upon the increased salience of, or top down expectancies for, ‘other’s things’ (see Sui, Sun, Peng, & Humphreys, 2014). In Chapter 4, other-ownership only appeared to influence movement kinematics when acting in the presence of one obstacle; rather than two; suggesting that the visuomotor system may only be sensitive to other-ownership when contextual demands allow alterations in action performance, without significant cost to action production (as is potentially the case in needing to navigate two obstacles).

In addition, we failed to consistently identify any motoric effects when an other-owner was the experimenter in Chapter 2 and 3 (instead observing facilitated avoidance for the mug belonging to an unknown other in Chapter 2), reflecting an unanticipated difference between the work of Constable et al. (2011; 2014) and the findings of the present thesis. It is unclear *why* their recruitment of the researcher was successful in eliciting deviation in mug positioning from the torso (which we interpreted to reflect avoidance processes for others’ property); while we failed to observe significant effects for property belonging to the experimenter in the affective compatibility task, even in a similar task context (requiring participants to physically interact with the items). It is of course possible that the spatial deviations observed in Constable’s work do not in fact reflect avoidance behaviour, as proposed. However, as so little is presently known about the manner in which other-ownership is cognitively represented, and how it comes to influence response processes, further research is required to better understand the causes of such disparities.

Future directions

Theoretical challenges

The relative paucity of work exploring *other*-ownership effects (relative to self-ownership) at present means that there remains much for future studies to investigate.

Firstly, there exists an overarching need for further consideration of how to suitably operationalise ownership; controlling for contaminating factors such as choice, preference, and familiarity (if also using self-ownership as a level); while maintaining the ecological validity of the stimuli and authenticity of participants' experiences of ownership in experimental contexts (note that Experiment 5 and 6 did remove choice and differences in low-level perceptual factors; however participants still owned and used the water bottles prior to testing). Paradigms such as the label-shape matching task (Sui et al., 2012) do successfully reduce higher-order contaminating variables, such as choice and preference, and control lower-level perceptual features and stimulus exposure (familiarity). However, it can be argued that much of what makes ownership interesting as a non-perceivable; socio-culturally constructed stimulus feature is also eliminated. Findings from such 'pure' paradigms are informative about how self-ownership, which is *seemingly* underpinned to a degree by a core self-object association (for example, similarly elicited by choice, Huang et al., 2014) likely affects fundamental cognitive processes in everyday contexts.

However, the arbitrary nature of the label-shape associations and task context may be insufficient for gaining understanding of how other-ownership cues, which appear to be much subtler, and rooted in the right to use and respect other's belongings, influence cognitive and motor processes. For example, interacting with a mug *chosen* by the experimenter, but not owned by them, does not elicit the same kinematic effects as interacting with a mug *owned* by the experimenter; while both self-choice and self-ownership produces similar kinematic patterns (Constable et al., 2014). Therefore, while choice appears sufficient to produce a self-object association like that of ownership (Huang et al., 2017), the influence of other-ownership knowledge on cognitive processes appears more greatly tied to the notion of property. At present, the temporal nature of visuomotor self and other-ownership effects remains largely unexplored (although see Sparks et al., 2016). For example, akin to the 'instantaneous' effects of self and other label-shape associations, do the types of visuomotor effects observed in the present thesis and the work of Constable and colleagues (2011, 2014, 2016) emerge when ownership of an object is assigned to both self and experimenter at the start of the testing session? Future research should endeavour to explore this, as one route for reducing contaminating variables (such as self-object familiarity), while maintaining an ecologically valid experimental construct of ownership that appears necessary for exploring other-ownership effects.

In addition, given that other-ownership effects are sensitive to contextual factors, such as experimenter presence (Constable et al., 2014), elements of task designs and the broader testing session, that may typically be overlooked, must be carefully considered in terms of their possible effects on other-ownership conditions. For example, if utilising the researcher as the other-owner, even experimental demeanour and consistency in the dyad between participant and researcher potentially requires close attention. Rather than situating the contextual and interpersonal sensitivity of other-ownership effects as a contaminant requiring elimination, the mediation of other-ownership effects by contextual and social conditions presents an interesting avenue for future investigation.

How characteristics of the other owner and interpersonal behaviour mediate action effects has yet to be pertained. However, evidence that others' faces which possess greater levels of social threat (e.g., boss vs. lab mate) receive recognition advantages over less threatening others (Liew, Ma, Han & Aziz-Zadeh, 2011) suggests that social differences in hierarchy or status as a mediator of responses to other-owned property should be explored. For example, do individuals take even greater care when moving in the presence of obstacles if the owner is of greater social status? Whether the researcher is an undergraduate or eminent professor may shape experimental findings. Similarly, if the other-owner is a close friend, are the differences in action performance for other-ownership identified in the present thesis, and Constable's (2011; 2014; 2016) work, attenuated? Motoric sensitivity to others' belongings may be even more tied to social context due to its socioconstructed nature and implications for social relations. Given that findings from face processing advantage work identify that contextual factors, such as priming threat (Guan et al., 2015), improve other-face processing performance (reducing the self-face bias) should prompt future work to endeavour to explore how (social) context mediates embodied ownership effects. For example, given that individuals engage in behaviour such as automatic mimicry in order to facilitate social interactions (Chartrand & Bargh, 1999; Maddux et al., 2008), and such smoothing techniques are recruited even more so when individuals feel ostracised (Lakin et al., 1999); does inducing a sense of ostracism mediate the care taken when moving in the presence of property owned by the individual ostracising?

Finally, alongside exploring the contextual mediators and boundary conditions (for example, the temporal robustness of effects) of ownership effects, another route through which to potentially gain greater insight, is to extend investigation to different populations who likely possess greater sensitivity to the notion of property. For example, given the early development of attachment to objects (Furby & Wilke, 1982; Lehman et al., 1995) and the possession of a concept of ownership that appears quite concretely rooted in the rights to use objects (especially at only around two years of age; Ross, 1996; Neary & Friedman, 2014); exploring whether children exhibit similar (and possibly more tangible) embodied motor effects for self-owned belongings; but also when interacting with others' property, will be one interesting route for exploration.

Future research should also seek to extend the exploration of visuomotor biases for property to a clinical sample whose disorder is characterised by the tendency to over-acquire possessions to a dysfunctional degree, and experience extreme difficulty discarding belongings, even when some possessions have little to no functional value (Steketee & Frost, 2003); those with hoarding disorder (American Psychiatric Association, 2013). Although hoarding was once considered a symptom or subtype of obsessive-compulsive disorder, since the publication of the 5th Diagnostic and Statistical Manual of Mental Disorders, it now exists as a clinical diagnosis in its own right (American Psychiatric Association, 2013). To the best of my knowledge, little is currently known about whether hoarding is, at least in part, underpinned by biased perceptual and visuomotor processing of self-associated objects. Instead, research concerning associated cognitive processing characteristics has tended to focus on more general impairments associated with hoarding behaviour, such as memory impairments (Hartl et al., 2004). Given that those with hoarding disorder experience hypersentimentality for their personal possessions (Frost, Hartl, Christian & Williams, 1995; Grisham et al., 2009), it may be interesting to futuristically explore whether they therefore exhibit greater embodied affective responses for self-owned belongings (heightened approach tendencies for property). If such approach biases were observed; it could prompt the development of Approach-tendency bias modification training programmes as one psychological treatment method; which are proven to have some success in attenuating maladaptive biases exhibited for stimuli relevant to disordered behaviour in other clinical groups, such as those with alcoholism (for example, see Spruyt et al., 2013; Eberl et al., 2014; Ostafin, Palfai & Wechsler, 2003).

Owning new methods

Alongside the need to greatly expand the study of other-ownership in future research, the methods used to consider such subtle effects requires further consideration. Indirect evidence (behavioural, see Constable et al., 2011, and through functional neuroimaging; see Turk et al., 2011) indicates that motor affordances of manipulable objects are mediated by ownership, elicited when viewing objects that the participant owned, compared with objects owned by another individual. However, the mediation of the recruitment of motor regions by ownership (in an embodied fashion) can more directly be established through Motor Evoked Potentials (MEPs). MEPs are elicited by delivering a brief, single pulse of Transcranial Magnetic Stimulation (TMS) to a region of the primary motor cortex (M1) contralateral to the associated limb or bodily region identified for investigation (although for use of a paired-pulse procedure, see Oliveri et al., 2004). The pulse subsequently stimulates neurons in the region of the cortex proximate to the coil. Electromyography (either electrodes inserted into the muscle, or adhered to the surface of the skin above the muscle) is used to record the evoked muscle activity that results from the stimulation of the associated motor region (see Figure 16; Rothwell, 1997, Rothwell et al., 1999), allowing precise measurement of the functioning, and corcticospinal connectivity, of neural populations within the motor system.

Although most pervasively used as a technique to assess the functional integrity of the corticomotor pathway when it may have suffered damage. For example, following stroke (for a review, see Talelli, Greenwood, & Rothwell, 2006, Stinear, 2010); cognitive neuroscience has also adopted MEPs as a measure through which to more directly investigate the motor system. For example, object affordances, the finding that simply viewing common objects results in activation of the premotor cortex (e.g., Grafton et al., 1997) can also be investigated via the mediation of MEP amplitudes after TMS applied over M1, as regions involved in selecting and activating object-directed action plans upon passive viewing, such as the premotor-parietal circuits, project to the primary motor cortex (Rizzolatti & Luppino, 2001). Buccino, Sato, Cattaneo, Roda, and Riggio (2009), investigated the notion of action affordances during the passive viewing of graspable objects (drinking receptacles with intact and broken handles), by measuring MEP amplitude of the right FDI, *first dorsalis interosseous*, a muscle in the hand recruited during grasping. As anticipated under an affordance account of grasp planning, objects with the handle oriented to the side of space of the recorded hand (right) elicited MEPs of a greater amplitude than those oriented to the left, suggesting that the corticomotor network supporting the execution of grasping actions is sensitive to affordances. The amplitude was significantly reduced for the ‘ungraspable’ broken handle (Buccino et al., 2009, see also McNair, Behrens & Harris, 2017).

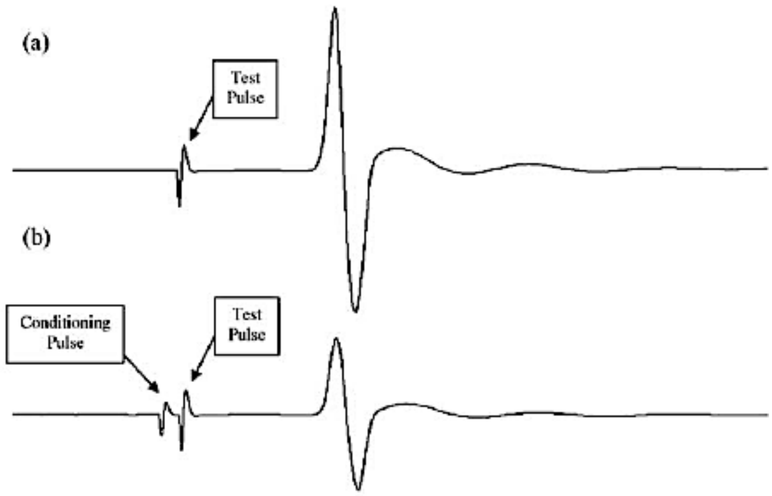

Figure 16. Example of a motor evoked potential recorded using surface electromyography, (a) illustrates an MEP using a single pulse stimulation and (b) resulting from a paired pulse technique (from Feil & Zangen, 2010).

Dissatisfied with the challenges of using indirect measures (such as reaction time and spatial differences in movement kinematics) in establishing such subtle motoric effects, and the limited ability such measures offer in distinguishing response patterns resulting from action planning, rather than alternative mechanisms; we explored the recruitment of more direct means through which to measure embodied ownership effects, by localised neurophysiological measures of motoric activity, during the production of this thesis (see Appendix C). Technical issues, combined with time constraints, ultimately prevented the collection of sufficient data for analysis and inclusion in the present work. However, future research would benefit from consideration of MEPs as a measure of motor processes when exploring embodied ownership effects.

Overall summary

This thesis has further extended findings concerning the effects of ownership status on visuomotor behaviour; while also highlighting the methodological and theoretical challenges of elucidating the embodied effects of other-ownership. Chapter 2 presented findings suggestive of an affective compatibility effect (in this case, the facilitated performance of approach movements) for self-owned property; alongside some tentative evidence that other-owned property primes avoidance responses (although this effect was only present under conditions of increased other-ownership stimulus probability). Given that the paradigm developed in Chapter 2 inherently confounded attentional factors, and embodied motor effects for other-ownership have, to date, been most consistently elicited during real world motor movements, Experiment 4 (Chapter 3) developed a version of the task requiring participants to physically manipulate the self and other-owned property, moving the mug toward or away from the body. The spatial and temporal parameters of movement performance were recorded using motion-tracking technology. Further supporting a motoric basis for the effects elicited in Chapter 2, participants displayed response initiation biases when producing approach movements for self-owned property. Therefore, self-ownership does appear to prime affectively congruent motor responses.

However, future research should endeavour to reduce the potentially contaminating effects of other variables inextricably intertwined with ownership under ecologically normative conditions; such as choice, preference, and familiarity; which are also likely to mediate the evaluation of stimuli, and therefore contribute to the congruency effects observed. Somewhat surprisingly, given that previous research has observed consistent mediation of the kinematics of interactions with property belonging to another, Chapter 3 failed to observe a robust effect of other-ownership status on the facilitation of congruent (avoidance) movements. Given that the present thesis failed to consistently elicit effects of other-ownership in object-directed action contexts; Chapter 4 explored the influence of ownership on an element of environmental interaction that has yet to be explored, obstacle avoidance.

Alongside the influence of ownership status during object-directed action, how we navigate movements in the presence of objects belonging to the self and others is of equal interest; particularly as other-ownership may possess more salience in obstacle avoidance contexts, where identify-related features of non-target objects that mediate the consequences of collision influence the degree of care (movement deviation) taken. We observed that ownership status can influence the movement paths executed when reaching for a target in the presence of own or experimenter-owned obstacles. Specifically, participants maintained greater limb-obstacle passing distance when reaching for a target while the experimenter’s property was within the workspace. However, this effect was only present when navigating movements in the presence of one obstacle; rather than two. Therefore, it is possible that the visuomotor system may only be sensitive to other-ownership when contextual demands, such as the requirement to plan and execute a more complex avoidance movement (navigating two objects), or the requirement to quickly and accurately produce object-directed action (during speeded approach-avoidance tasks), allow alterations in action performance, without significant cost to action production.

Finally, this thesis illustrated the challenging nature of investigating such subtle effects of other-ownership status using indirect measures, such as response time (which, in addition to action planning and execution, reflect other cognitive processing mechanisms), and spatial alterations in movement paths (which, albeit sensitive, are vulnerable to greater deviation as a function of inconsistent wrist positioning, than the deviation differences arising from the variables of interest). Future research that endeavours to further elucidate the influence of other-ownership status on the visuomotor system should consider adopting more direct outcome measures of motor preparation; such as motor evoked potentials.

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Appendix A

Edinburgh Handedness Questionnaire

Study Title:
Researcher Name:
Participant ID Code:

Please fill in this questionnaire only if you have agreed to take part in our studies and have signed the appropriate consent form. Please note that you may omit answering any question without penalty and that this information will be kept strictly confidential.

For each of the activities below, please tell us:
Which hand do you prefer for that activity? Do you ever use the other hand for the activity?

	Left (**L**) or Right (**R**)	Do you ever use the other hand? **Y**es or **N**o
Signing		
Writing		
Drawing		
Throwing		
Using scissors		
Using a Toothbrush		
Using a Knife (without a fork)		
Using a Spoon		
Using a Broom (upper hand)		
Striking a Match		
Opening a Box (lid)		
Foot to Kick With		
Bat (swing)		

1. **Do you consider yourself: (circle appropriate)**

   Right-handed   Left Handed   Ambidextrous (both hands)

2. **Is there anyone in your family who is Left-handed? (circle appropriate)**
   Yes or No
   If yes, who ______________________________

3. **Did you ever change handedness? (circle appropriate)**
   Yes or No
   If yes, please explain ______________________________
   ____

4. **Is there any activity not on this list that you do consistently with your left hand? If so, please explain** ______________________________

This handedness questionnaire was adapted from: Oldfield, R.C. (1971) The assessment and analysis of handedness: the Edinburgh inventory. *Neuropsychologia*, *9(1)*, 97-113.

Appendix B

Effect of ownership for each action level for Experiments 1 - 3.

Experiment	Comparison	df	*t*	*p*
Experiment 1	**Approach**			
	Own vs Experimenter	34	-2.84	.008
	Own vs Unknown Other	34	-4.07	< .001
	Own vs Unowned	34	-4.15	"
	Own vs All other (avg)	34	-3.78	.001
	Avoid			
	Own vs Experimenter	34	4.86	< .001
	Own vs Unknown Other	34	5.04	"
	Own vs Unowned	34	4.89	"
	Own vs All Other (avg)	34	5.15	"
Experiment 2	**Approach**			
	Own vs Experimenter	22	-.53	.603
	Own vs Unknown Other	22	-2.12	.046
	Own vs Unowned	22	-.93	.361
	Own vs All other (avg)	22	-1.27	.218
	Avoid			
	Own vs Experimenter	22	7.92	< .001
	Own vs Unknown Other	22	8.22	"
	Own vs Unowned	22	5.55	"
	Own vs All Other (avg)	22	7.39	"
Experiment 3	**Approach**			
	Own vs Unknown Other	28	-4.31	< .001
	Avoid			
	Own vs Unknown Other	28	1.708	.099

Appendix C

Motor Evoked Potential (MEP) lab set-up

During the production of this thesis, significant time was dedicated to establishing an MEP lab (see Figure 17), to directly investigate whether the modulation of MEP amplitude (right FDI at rest, during passive viewing of coffee mugs) by object affordance was further mediated by ownership status. Broadly, we intended to utilise Buccino et al.'s (2009) affordance task, including ownership as a factor. We predicted that MEP amplitude for mugs with handles oriented to the right would be mediated by ownership, with a reduction in MEP amplitude for the experimenter's property, relative to own and unowned stimuli.

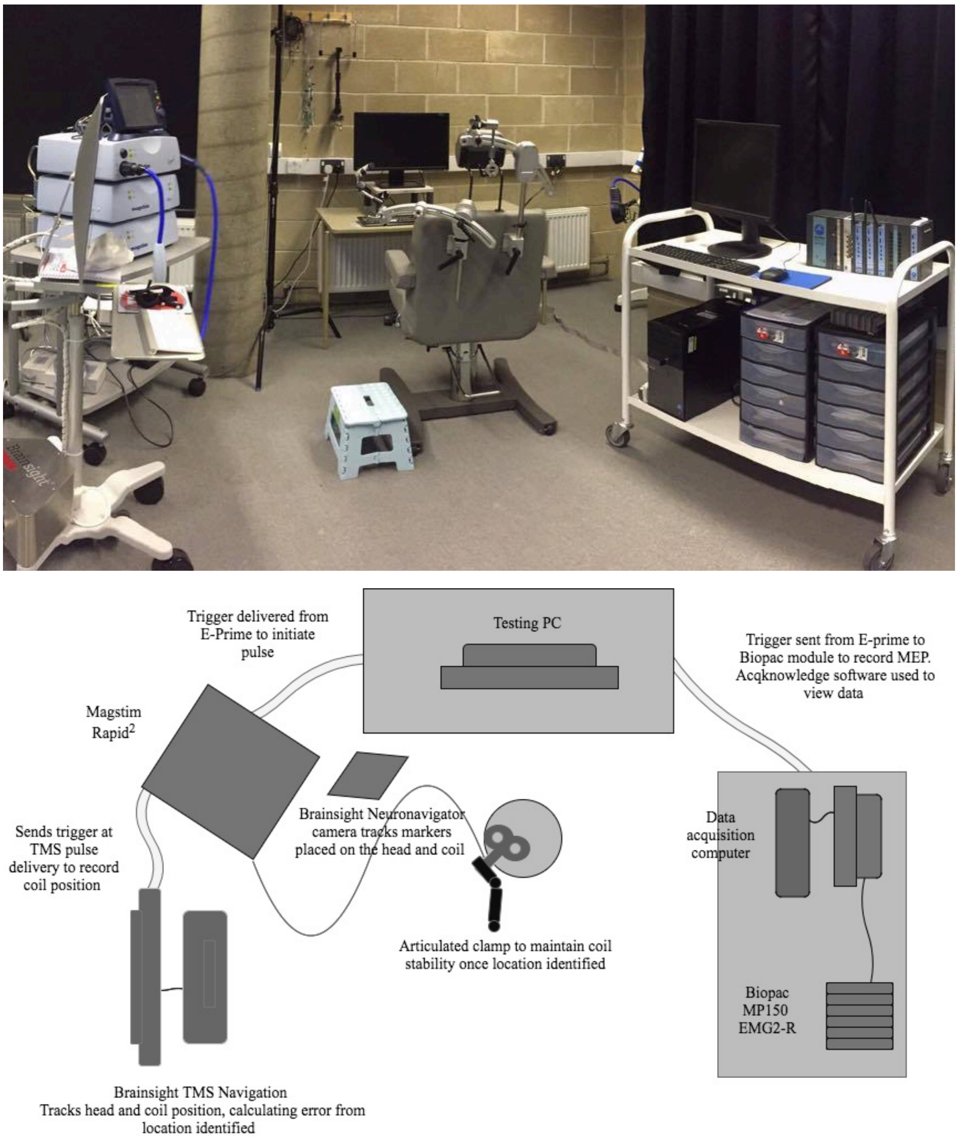

Figure 17. The completed lab set-up for eliciting motor evoked potentials.

EMG recordings were obtained using pre-gelled disposable surface electrodes, placed in a standard belly-tendon montage (see Figure 18). TMS was delivered to the associated region of the left hemisphere of M1, using a figure of eight coil, 200 ms after mug presentation (handle oriented to the left or right, own, experimenter's and unowned). The suitable stimulation site for each participant was localised by the elicitation of a visible twitch in the target site, with stimulation intensity then reduced until five out of ten MEPs of at least 50 µV was obtained. Subsequent stimulation intensity was then set at 120% of this threshold; a normative procedure, see Rossini et al., 1994).

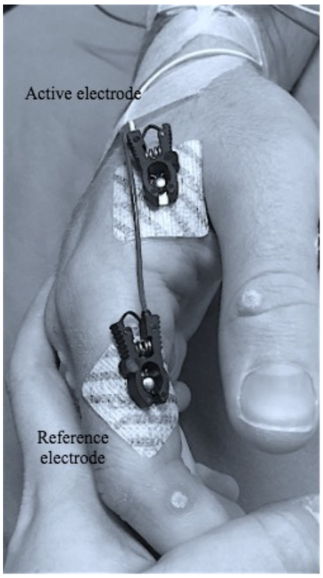

Figure 18. Belly-tendon montage electrode placement for the FDI muscle.

An articulated clamp was used to maintain coil position, and head and coil location were tracked using Brainsight TMS Navigation (Brainsight, Cardiff, UK). Extensive piloting was conducted, however, continual equipment limitations prevented completion of testing sessions. Specifically, persistent overheating (and therefore, shut down) of the TMS coil was experienced. This resulted from the machine used (Magstim Rapid^2, The Magstim Company Ltd, Whitland, UK) possessing lower overall output, and therefore needing to be operated at a greater percentage of overall capability; than machines typically recruited for MEP investigation (Magstim 200, The Magstim Company Limited, Whitland, UK, for further discussion of stimulator differences, see Sommer et al., 2006).