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Language and memory for object location

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ABSTRACT

In three experiments, we investigated the influence of two types of language on memory for object location: demonstratives (*this*, *that*) and possessives (*my*, *your*). Participants first read instructions containing demonstratives/possessives to place objects at different locations, and then had to recall those object locations (following object removal). Experiments 1 and 2 tested contrasting predictions of two possible accounts of language on object location memory: the *Expectation Model* (Coventry, Griffiths, & Hamilton, 2014) and the *congruence account* (Bonfiglioli, Finocchiaro, Gesierich, Rositani, & Vescovi, 2009). In Experiment 3, the role of attention allocation as a possible mechanism was investigated. Results across all three experiments show striking effects of language on object location memory, with the pattern of data supporting the Expectation Model. In this model, the expected location cued by language and the actual location are concatenated leading to (mis)memory for object location, consistent with models of predictive coding (Bar, 2009; Friston, 2003).

1. Introduction

The relationship between language and non-linguistic representations is a fundamental topic in the cognitive sciences. Often this relationship is approached from the standpoint of the extent to which non-linguistic representations are necessary for language comprehension (e.g. within the framework of 'embodied' cognition; cf. Barsalou, 1999). However, equally important is the extent to which language can influence non-linguistic processes (Coventry, Christophel, Fehr, Valdés-Conroy, & Herrmann, 2013). Language can direct the attention of a conspecific to the spatial world; spatial expressions, such as *these coins* or *the cup is on the table* serve to direct the attention of a hearer to regions of space (Miller & Johnson-Laird, 1976). And the pairing of language with visual events and images also affects what is recalled about the spatial world. For example, Loewenstein and Gentner (2005) found that children performed better in a mapping task when spatial relations were paired with spatial language at encoding (e.g., "I'm putting the book on the shelf"). They argue that relational language fosters the development of representational structures that facilitate cognitive processing (see also Hermer-Vazquez, Spelke, & Katsnelson, 1999).

Language can facilitate the binding and maintenance of color-location conjunctions (Dessalegn & Landau, 2008, 2013; Farran & O'Leary, 2015). For example, in a memory experiment, four-year olds performed a task in which a target (e.g. a square split in half by two different colors) was presented which they then had to find in an array. Performance was enhanced if the target was accompanied by spatial cues (e.g., "yellow is on top"). There was no additional benefit for children verbalizing the linguistic cue themselves over just hearing the cue, as long as they had a stable understanding of the spatial terms (Farran & O'Leary, 2015).

As well as facilitating memory, language presented with a spatial scene can also lead to memory errors (Feist & Gentner, 2007; Gentner & Loftus, 1979). For instance, Feist and Gentner (2007) showed that recognition memory for spatial scenes was shifted in the direction of the spatial relational language (spatial prepositions) presented with scenes at encoding. In their study, participants saw with ambiguous pictures depicting spatial relations accompanied with or without spatial sentences. When participants responded in a later yes-no recognition task, spatial language at encoding was associated with more false positives (in cases where the spatial language at encoding was associated with a more prototypical version of the spatial relation than the relation actually shown). Feist and Gentner (2007) suggest this is a result of an interactive encoding of language and visual memory, in which language influences the way people encode visual scenes. More broadly, language can be used as a tool in a task to aid memory and/or processing of spatial information (see for example Frank, Everett, Fedorenko, & Gibson, 2008; Li, Abarbanell, Gleitman, &

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Papafragou, 2011) consonant with some weaker variants of so-called ‘linguistic relativity’ (see Wolff & Holmes, 2011 for review).

The effects of language on memory are not limited to spatial cognition. It has also been found that presenting possessive pronouns in combination with a memory task enhances response times and memory for objects (Shi, Zhou, Han, & Liu, 2011). Shi et al. presented Chinese nouns preceded by a pronoun (*my*/*his*). Participants had to scale the presented nouns for likeability and were given a surprise memory test. In the *my* condition, participants responded faster and showed a better memory performance for the nouns than in the *his* condition.

Although it has been shown that language can influence memory, it has yet to be demonstrated *how* it does so. In this paper, our focus is on the (possible) influence of spatial demonstratives and possessives on memory for object location. The continuous nature of object location memory errors affords testing directly between a number of possible mechanisms regarding how language affects memory for object location.

Spatial demonstratives (e.g., *this*/*that*) are among the earliest words children learn (Diessel, 2006) and have been shown to be associated with discrete zones of peri-personal (near) and extra-personal (far) perceptual space (Coventry, Valdés, Castillo, & Guijarro-Fuentes, 2008; Diessel, 2006; Maes & de Rooij, 2007; Stevens & Zhang, 2013; cf. Peeters, Hagoort, & Ozyürek, 2014). However, this distinction is flexible and graded. Near space can be extended or contracted by tool or weight use (Longo & Lourenco, 2006), and the use of *this* is similarly extended when participants use a stick to point at objects (Coventry et al., 2008). In addition to distance, demonstrative choice is also affected by other variables. Coventry, Griffiths, and Hamilton (2014) explored the relationship between object knowledge and distance on both demonstrative choice in English and memory for object location. Across seven experiments they found that object familiarity (i.e., familiar versus unfamiliar colored shapes), object ownership (whether the participant owned the object or not) and object visibility (whether the object was covered with an opaque cover or not) all affected demonstrative choice to describe object location and (non-linguistic) memory for object location. For example, unfamiliar objects (low frequency color-shape combinations, such as a viridian nonagon) were misremembered as being further away than they actually were relative to familiar objects (e.g., a red square). In order to account for both the demonstrative choice data and the memory data, Coventry et al. (2014) proposed a model of the influence of object knowledge on both measures. In their *Expectation Model*, memory for object location is a combination of where an object is located and where an object is expected to be located (see Fig. 1a). The expectation of the objects’ location is combined with the actual object location (with an associated estimation error) in memory, as follows:

$$M_D = f(D_a, D_{exp}, D_{err})$$

where M = signed memory error, D = distance, $_a$ = actual, $_{exp}$ = expected and $_{err}$ = estimation error.

Coventry et al. (2014) acknowledge that the model may operate at encoding of object location or at retrieval. If the former is the case, it is assumed that an object expected to be in peripersonal space (such as an object owned by the participant), activates peripersonal space as the participant encodes object location, and therefore that the actual representation of location at encoding, and later memory is a concatenation of expectation of where an object is most likely to be located and where it is actually located. The alternative possibility is that the location errors emerge only at retrieval, consistent with effects found in the verbal overshadowing (Alogna et al., 2014; Schooler & Engstler-Schooler, 1990) and eye-witness testimony literatures (Loftus, Miller, & Burns, 1978; Loftus & Palmer, 1974; McCloskey & Zaragoza, 1985).

Coventry et al. (2014) did not examine the influence of language on memory for object location, but by extension, the expectation model makes predictions regarding how language might impact upon memory for location. As *this* is associated with near space and *that* with far space, one can assume that the expected distance value associated with *that* would be greater than the expected value distance associated with *this*. Combined with the actual distance, the expectation model therefore predicts a main effect of language on memory for object location, with *that* associated with (mis)memory for objects further away than they actually were compared to *this* (Fig. 1a). Consistent with earlier studies, an effect of location, in which memory for objects further away is worse than for objects closer by, would be expected.

In contrast to the expectation model, there is a considerable body of work within an ‘embodied cognition’ framework providing evidence for the importance of congruence/incongruence effects between language and space that makes different predictions from the expectation model. A growing number of studies suggests that participants’ performance is affected by congruence/incongruence between language or concepts and space. For example, it has been shown that participants respond more quickly to positively valenced stimuli in a congruent high location than an incongruent low location, and vice versa for negative stimuli (e.g., Barsalou, 2008; Meier & Robinson, 2004; cf. Lynott & Coventry, 2014). What one might term a ‘congruence account’ has been extended to movement planning, whereby movements are prepared based on given language (Bonfiglioli, Finocchiaro, Gesierich, Rositani, & Vescovi, 2009; see also Stevens & Zhang, 2013). For example, Bonfiglioli et al. (2009) required participants to grip an object after listening to an instruction that indicated whether the object was near or far. A significant interaction was found in which performance was better when the descriptive language and space were congruent compared to incongruent situations - reaction times were significantly longer when language was incongruent with space compared to when language and space were congruent. Bonfiglioli et al. (2009) therefore concluded that they found

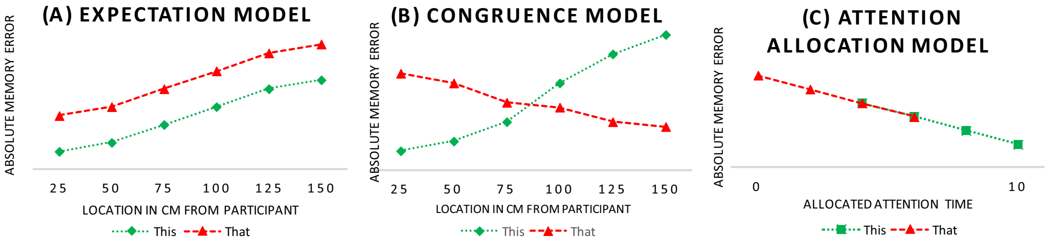

Fig. 1. Predictions from the different models, from left to right: a. Expectation Model, b. Congruence Model, c. Attention Allocation model. On the y-axis the difference between the actual location and the remembered location is presented, a higher value on the y-axis means an object is remembered as being further away than it actually was. In a and b, the six distances from the participant (in cm) used in Experiment 1 and 2 are plotted. In c, the x-axis represents the total possible fixation time (10 s) for participants in Experiment 3. The lines represent the influence of demonstratives (*this*/*that*). In c more attention leads to a smaller memory error, and ‘*this*’ is predicted to elicit more attention than ‘*that*’.

interference effects from the used pronouns at the level of movement planning. In line with the Theory of Event-Coding (TEC) (Hommel, Musseler, Aschersleben, & Prinz, 2001), we extend these findings in the action literature to memory. In the TEC, it is suggested that perception and action share an indistinguishable underlying representational medium. This would entail that, for example, memory and action are based on the same cognitive codes. Therefore, if an effect of interference due to incongruence is found in action planning, it should be found in memory (Hommel et al., 2001). When we extend the effects of congruence on action to memory for object location, we would therefore predict a similar interaction. Congruence in language and space would be expected to enhance the accuracy of memory for location, with greater errors (without specification of direction) when there is a mismatch between the demonstrative and location, as follows:

$$M_D = f(D_a, C, D_{err})$$

where M = signed memory error, D = distance, $_a$ = actual, C = congruence of language with location and $_{err}$ = estimation error (Fig. 1b). This means that when a congruent demonstrative is used to describe an object's location (e.g., *this* for an object close by, or *that* for an object further away), memory for object location is expected to be more accurate than when language and situation are incongruent (e.g., *that* for an object close by, *this* for an object further away).

Distinct from both the Expectation and Congruence models, the possible effect of language on memory should also be considered in relation to the allocation of attention. A large literature shows that language affects where one looks in a visual scene, for example in terms of fixating particular objects when they are mentioned (e.g., Allopenna, Magnuson, & Tanenhaus, 1998; Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). Building on this earlier work, it is possible that language also affects the amount of time one spends looking at an object. Given that *this* is associated with proximity to a speaker, one might speculate that participants might look longer at an object at a location when preceded with *this* compared with *that*, as visual attention is allocated preferentially to near objects compared to objects further away (Garrido-Vásquez & Schubö, 2014). Following evidence that longer looking times are associated with better memory performance (e.g., Huebner & Gegenfurtner, 2010), one might then predict better accuracy of recall for trials preceded with *this* compared with *that*. In Experiment 3, we used eye tracking during the encoding phase, to investigate whether differences are driven by attention allocation (Fig. 1c). In summary, the goal of the present studies was to test whether language affects memory for object location, and to elucidate the mechanism involved. Specifically, we aimed to tease apart these three accounts by examining the effects of demonstrative and possessives on memory for object location. The first experiment tested whether spatial demonstratives affected memory for object location with contrasting predictions from two possible models of how language affects memory: congruence vs. expectation. Experiment 2 tests whether the effects found for demonstratives also occur for possessives (*my*/*your*) – terms which have also been associated with the peripersonal/extrapersonal space distinction. Experiment 3 tests predictions from the attention allocation model using eye tracking.

2. Experiment 1: The influence of demonstratives on spatial memory

This experiment tested whether spatial demonstratives paired with an object at encoding affected memory for object location, with objects placed at varying distances in front of participants on a table and then removed. The main goal was to test between the expectation and congruence models. Critically, the expectation model predicts a main effect of demonstrative on object location memory and the congruence account predicts an interaction between demonstrative and distance.

2.1. Method

2.1.1. Participants

Thirty-six native English speaking students[1] were tested, receiving either course credit or payment for their participation. Stereoacuity was measured using the Randot Stereotest (Stereo Optical Inc. Chicago, USA). Two participants did not have a threshold of at least 40″ (arcseconds) and therefore were excluded. Two additional participants were excluded because they had more than 10% incorrect answers in the memory task. This left 32 participants, 9 males and 23 females, with an age range of 18–31 years old (*M* = 20.78, *SD* = 3.14).

2.1.2. Materials

Six distinguishable, different colored shapes on plastic discs (e.g. yellow triangle/blue heart), 6.5 cm in diameter, were placed at six different locations. The locations were spaced equidistantly along a midline from the participants' edge of a large conference table (L = 320 cm, W = 90 cm), starting at 25 cm from the participant up to 150 cm. The three dots that were closest to the participants were located within peripersonal space, while the remaining three dots were within extra-personal space (confirmed for each participant). The table was covered with a black cloth so that no spatial cues were present.

2.1.3. Procedure and design

Participants were asked to sit as close to the table as was comfortable, to ensure that all participants were approximately the same distance from the objects. Then, they played a 'memory game' as used previously by Coventry et al. (2014); participants were told the experiment was testing memory for object location. On each trial, the participant read out an instruction card indicating which object had to be placed on which location. The instructions all had the form: "Place DEMONSTRATIVE, OBJECT COLOR, OBJECT NAME, on the COLOR dot" (e.g., "Place this red triangle on the blue dot"). Following the instruction, participants closed their eyes while the experimenter placed the object as instructed. The participant was then given 10 s to view the object and to memorize the object location before the object and the dots were removed and the experimenter went behind a curtain to present an indication stick. Next, the participant verbally instructed the experimenter to match the near edge of the indication stick to the remembered near edge of the object location. Participants were then required to verbally indicate the demonstrative used on the instruction card to ensure they had attended to the instructions (see Fig. 2).

There were two demonstratives (*this*/*that*) and a neutral determiner (*the*), six locations, and six objects. Participants were presented with six practice trials, after which 54 experimental trials were conducted (consisting of 3 trials of every term on every location: 3 × 3 × 6). The indication stick was presented at a distance of 10 cm (counterbalanced to be further or nearer) from the actual location. Within the first 10 trials, there were three filler trials in which the indication stick was presented at a distance of 20 cm from the object location, to prevent the initial placement of the stick becoming a cue for the object location. Every trial in which a participant could not remember the demonstrative was repeated at the end of the experiment (if a participant couldn't remember >10% of the trials s/he was excluded). Also trials in which a participants' estimate of the object location was >25 cm from the

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[1] Sample size is based on Coventry et al. (2014).

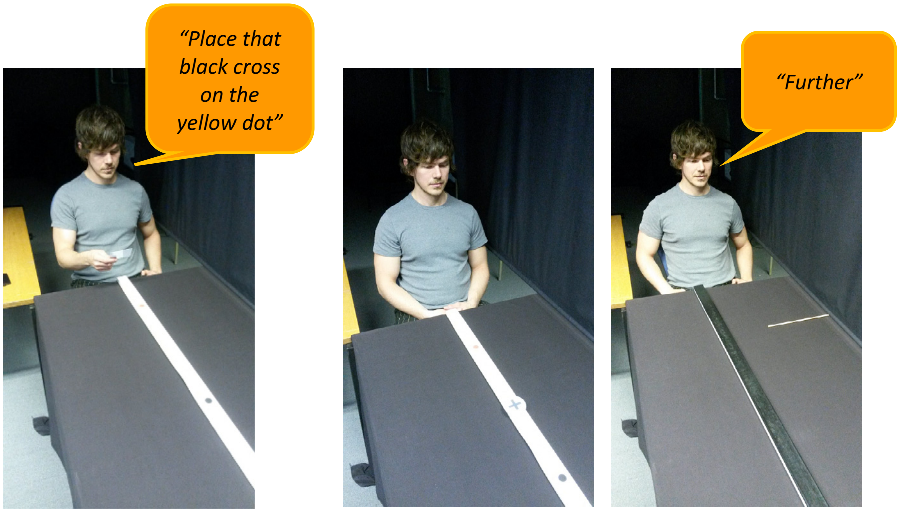

Fig. 2. In the "memory game", the participant reads out the instruction card, then memorizes the object location and finally instructs the experimenter to move the indication stick so it is aligned with where the edge of the object was.

original location were repeated. If the criterion was not met after repeating, the trial was eliminated. At the end of the experiment, reaching distance was measured for each participant. Every participant could reach only the first three dots. The 'memory game' cover meant that participants were not aware that we were interested in the differences between demonstratives (confirmed during debrief).

2.2. Results and discussion

The memory displacement data – that is, the difference between the recalled distance and the actual distance between the recalled distance and the actual distance measured in centimeters – are displayed in Fig. 1 (see also Table 1, supplementary data). Note that a positive value indicates that an object was (mis)remembered as further away than it actually was. A 3 × 6 (demonstrative × location) ANOVA was performed on the memory displacements. The assumption of sphericity was violated in both the location and the demonstrative × location analyses. We therefore used the Greenhouse-Geisser correction for these analyses. There was a main effect of demonstrative, $F(2,62) = 6.68$, $MSE = 10.04$, $p < 0.01$, $\eta p^2 = 0.18$, showing an effect of language on memory for object location: follow up (LSD) tests showed significant differences between locations accompanied by the *that* ($M = 2.94$, $SE = 0.42$) compared to both the *this* ($M = 2.01$, $SE = 0.41$) and the *the* ($M = 1.84$, $SE = 0.47$) conditions (both p's < 0.01; see Fig. 3). There was a marginal effect of location, $F(5,155) = 2.33$, $MSE = 25.49$, $p = 0.08$, $\eta p^2 = 0.07$, revealing that memory for object location deteriorated with distance, consistent with previous studies. Importantly, there was no interaction between demonstrative and location, $F(10,310) = 1.4$, $MSE = 9.13$, $p = 0.21$, $\eta p^2 = 0.04$. The results therefore support the expectation model rather than the congruence model; *this* leads to more accurate object location memory than *that*, irrespective of the congruence between the specific demonstrative and location. We next considered whether the same pattern of results might emerge with a different language manipulation involving possessives.

3. Experiment 2: The influence of possessives on spatial memory

Some studies have shown that ownership improves memory for objects (Cunningham, Turk, Macdonald, & Macrae, 2008; Shi et al., 2011; Turk et al., 2015) and influences how people physically interact with objects (Constable, Kritikos, & Bayliss, 2011). For example, Cunningham et al. (2008) had a participant and a confederate sort cards with pictures of shopping items into their own basket or the other person's basket. At the end of the trials participants completed a surprise memory test for the objects depicted on the cards. Participants had more accurate memories for self-owned objects than objects owned by a conspecific.

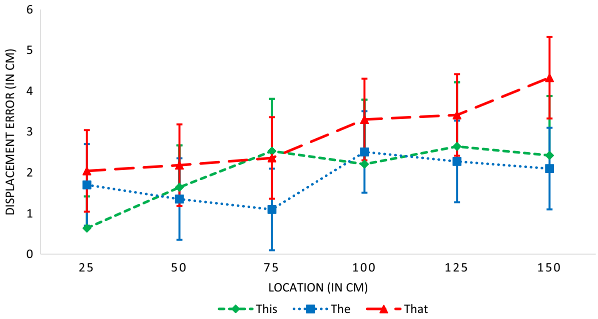

Fig. 3. Results of Experiment 1, error bars are 95% confidence intervals.

In another study, specifically targeting memory for object location, Coventry et al. (2014), found that object ownership affected memory for object location (and demonstrative choice). Using the memory game paradigm, participants were given a set of coins in payment at the start of the experiment, and the coins placed at different to-be-remembered locations were either those coins or coins owned by the experimenter of the same denominations. Participants misremembered the conspecific's coins as being further away than their own coins.

One of the problems with the ownership studies described above is that they cannot easily distinguish between an effect of the abstract concept of ownership and an effect of the possessives (*my*/*your*) used to indicate ownership during task instruction. For example, in the study of Coventry et al. (2014), coins were given to participants as participant payment at the start of the task to confer ownership, but language during the task itself involved by necessity the use of possessives (e.g., "Place your coin on the red dot") in order to disambiguate which coin was to be placed during the task. It is therefore unclear whether the effect of ownership is driven by the language indicating ownership (possessives in all cases), the conceptual representation of ownership itself, or a combination of the two. Here we investigated whether possessives have the same influence on memory for object location as did the demonstratives in Experiment 1, whether personal possessives <u>*alone*</u> are able to drive memory effects, and again, whether the expectation vs. congruence models offer a better account as to how possessives affect memory for object location.

3.1. Method

3.1.1. Participants

Thirty-nine native English speaking participants were tested, as in Experiment 1. Five participants in total were excluded as they did not score above the threshold of 40″ (N = 2), had more than 10% mistakes in the memory task (N = 2) or could not reach the 50 cm point (N = 1). This left 34 participants, 14 male and 20 female, with an age range of 18–44 years old ($M = 23.76$, $SD = 4.87$).

3.1.2. Procedure and design

The procedure was similar to Experiment 1, with the exception that the demonstratives were replaced with possessives (*my*, *your*; the *the* condition was retained). To allow us to distinguish between an actual ownership effect and a language effect of possessives, participants did not own any of the objects, and all objects were used in all language conditions.

3.2. Results and discussion

The memory displacement data are displayed in Fig. 4 (see also Table 1, supplementary data). A 3 × 6 (possessive × location) ANOVA was performed on the difference (in centimeters) between the actual position of an object and the memorized position. There was a main effect of possessive, $F(2,66) = 8.25$, $MSE = 7.62$, $p = 0.001$, $\eta p^2 = 0.2$, showing that objects in the *your* condition ($M = 1.89$, $SE = 0.43$) were remembered as being significantly further away than objects in both the *my* condition ($M = 0.81$, $SE = 0.34$) and the *the* condition ($M = 1.11$, $SE = 0.34$), both p's < 0.01; see Fig. 4). A significant effect of location was also found, $F(5,165) = 3.47$, $MSE = 18.07$, $p = 0.01$, $\eta p^2 = 0.1$, showing that accuracy deteriorated as the objects were placed further away. These results are compatible with earlier studies on ownership. However, as all objects were used in all language conditions, there was no actual sense of ownership over any of the objects; the ownership was only marked by the use of possessives. This shows that possessives on their own affect memory for object location.

Additionally there was an interaction between possessive and location, $F(10,330) = 2.25$, $MSE = 10.37$, $p = 0.03$, $\eta p^2 = 0.06$. As can be seen in Fig. 4, the interaction pattern is consistent with the expectation model and is not consistent with the congruence account: there is no cross-over between peripersonal and extrapersonal space as would be expected in the congruence account. However, it is the case that the effect of distance does seem to vary as a function of language. To further unpack this, we ran three one-way ANOVAs to test location effects by term, revealing that there was only a reliable peri-personal/extra-personal effect in the *your* and *the* conditions ($p < 0.05$). This effect was absent in the *my* condition ($p > 0.05$; see Fig. 4). This suggests that memory for possessed objects maybe particularly enhanced, overriding any effect of peripersonal versus extrapersonal space.

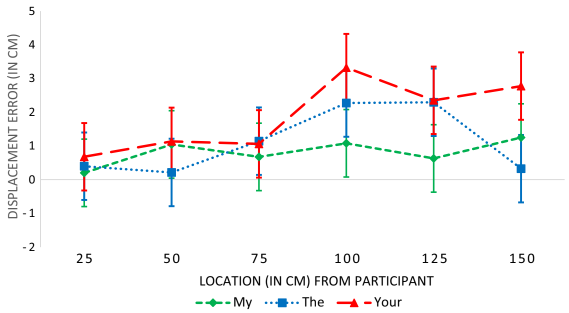

Fig. 4. Results of Experiment 2, error-bars are 95% confidence intervals.

4. Experiment 3: The influence of attention on spatial memory

So far the results are consistent the expectation account. However, it is important to also consider the possibility that the results might be driven by the allocation of attention. Visual attention is allocated preferentially to objects nearby, compared to objects further away (Garrido-Vásquez & Schubö, 2014) and longer fixation times lead to better memory performance (Huebner & Gegenfurtner, 2010). Therefore, the predictions of memory error in the Expectation Model and what we have coined an "Attention Allocation Model" are similar, but differ in underlying mechanism. The Expectation Model predicts that memory for object location is a function of the language used to refer to the object (and the expectation of location associated with that language) combined with the actual object location. The Attention Allocation model suggests that memory for object location is a function of the fixation time and the object location. The results of Experiment 1 could therefore be alternatively explained by the Attention Allocation Model - differences are driven by different fixation times, cued by *this* versus *that*, rather than differences in expectation values. In this experiment, we used eye tracking to measure participants' looking time during encoding. That allowed us to measure the time a participant is focused on the object in each language condition to see whether attention might account for the main effect of language reported above.

A second aim of Experiment 3 is to explore the connection between demonstratives and reference frames. As peri-personal space is the area within our grasp, this can be seen as an 'action space' in which objects are mapped onto an egocentric reference frame, compared to extra-personal space which may be mapped onto an allocentric reference frame (ter Horst, van Lier, & Steenbergen, 2011). If the language effect that was found in the first two experiments is driven by the expectation raised by the specific use of language, then this expectation may result in different use of reference frames. We explored whether encoding object location onto an egocentric reference frame resulted in more searching behavior along the sagittal line, to encode distance from the participant, compared to encoding onto an allocentric reference frame which could result in more searching behavior along the coronal line (see Fig. 5). Results could help distinguish between models that predict solely an influence of egocentric representations on spatial memory versus 'two-system' models that predict a parallel egocentric and allocentric representations in object location memory (see Burgess, 2006).

4.1. Method

4.1.1. Participants

Nineteen participants were tested with the same method as in Experiment 1. Three participants were excluded from the analysis as the eye-tracker could not be calibrated. This left 16 suitable participants for the analyses, 5 male and 11 female, with an age range of 18–22 ($M = 19.19$, $SD = 1.17$).

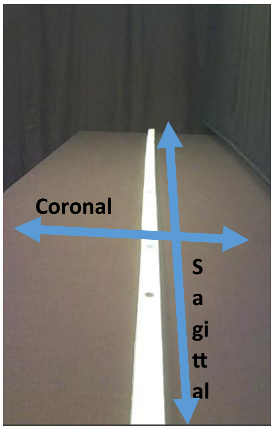

Fig. 5. Coronal and Sagittal plane of searching.

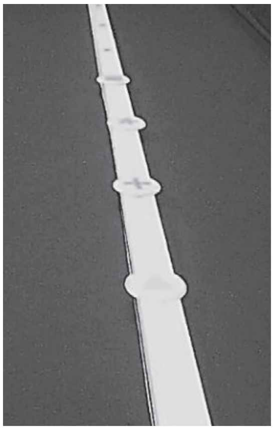

Fig. 6. Raw object sizes on the screen, during semantic gaze mapping.

4.1.2. Procedure and design

The procedure was based on Experiments 1 and 2, but in this experiment, participants wore SMI eye-tracker glasses (30 Hz binocular eye tracking glasses). For this reason, 4 positions were used – two locations in peripersonal space and two in extrapersonal space (the first location was too close for the eye-tracker and the furthest location was not useable because the area of interest was too distorted). Before the experiment started, the glasses were calibrated using marks on the wall. After that, calibration was validated four times throughout the experiment by having participants look at the four different locations on the table. The eye-tracking data were coded using semantic gaze mapping.[2] As the angle from the participant to the object was different for every location, the standard error in calibration of the eye-tracker image was slightly different per location. These distortions had to be accounted for in the semantic gaze mapping. Therefore, the coding was slightly less stringent for further locations compared to closer locations. For the furthest location, any fixation within an area of 6.5 cm (equivalent to the diameter of the object discs) around the object was marked as a fixation on the object. In the nearest location, any fixation within an area of 3.25 cm (half an objects' diameter) was marked as a fixation on the object (see Fig. 6).[3] The gaze mapping data were used in a 3 × 4 (demonstrative × location) design, investigating the differences in total fixation time (ms) on the object.

4.2. Results and discussion

The memory displacement data and the fixation times are displayed in Figs. 7 and 8 (see also Table 1, supplementary data). The memory data were analyzed in a 3 × 4 (demonstrative × location) ANOVA. A main effect of demonstrative was found, $F(2,30) = 5.77$, $MSE = 10.02$, $p < 0.01$, $\eta p^2 = 0.28$, in which recalled distances for object location in the *that* condition ($M = 1.77$, $SE = 0.68$) were significantly further away than those in the *this* condition ($M = -0.07$, $SE = 0.79$), $p < 0.05$. The *this* condition distances were also significantly closer than in the *the* condition ($M = 1.3$, $SE = 0.59$), $p < 0.05$ (see Fig. 7). This replicates the result of Experiment 1. There was also a main effect of location, $F(3,45) = 9.69$, $MSE = 29.77$, $p = 0.001$, $\eta p^2 = 0.39$, in which participants' accuracy deteriorated as locations were further away. There was no interaction effect between demonstrative and location, $F(6,90) = 1.61$, $MSE = 9.26$, $p = 0.15$, $\eta p^2 = 0.1$, which means that the effect of language was the same across locations.

To see whether the language effects found were driven by a mechanism as hypothesized by the Expectation Model or the Attention Attenuation Model, we next examined the gaze data collected during encoding. A 3 × 4 (demonstrative × location) analysis of object fixation time showed no effect of language, $F(2,30) = 0.13$, $MSE = 1974647.31$, $p = 0.81$, $\eta p^2 = 0.009$ ("*this*" $M = 5175.70$, $SE = 345.44$; "*that*" $M = 5230.97$, $SE = 257.65$; "*the*" $M = 5285.14$, $SE = 416.76$), suggesting that the language effect is not driven by differences in attention (see Fig. 8). There was a location effect, $F(3,45) = 4.66$, $MSE = 1997163.36$, $p < 0.01$, $\eta p^2 = 0.24$, showing that participants fixated longer on locations further away. However, this location effect could be due to the differences in coding caused by distance, as explained above. There was no interaction effect between demonstrative × location, $F(6,90) = 0.62$, $MSE = 1442394.41$, $p = 0.71$, $\eta p^2 = 0.04$.

In a second analysis, we explored the connection between demonstratives and reference frames, and specifically to test whether people use different coordinate systems to remember object locations, based on spatial language. Fixations were coded as sagittal searching behavior, if a sequence of two or more fixations fell within a range on either side (left/right) of the white location stick, the range being 3.25 cm from the sides for the closest location and 6.5 cm from the furthest location. These distances were based on the size of an object on the respective location as represented on the screen (the actual objects had a diameter of 6.5 cm). Fixations were coded as searching behavior along the coronal line if a sequence of two or more fixations fell within a range above or below the object location. The range was half an objects' size for the closest location and one objects' size for the furthest location along the coronal plane. Fixations coded as fixations on the actual object were excluded from this analysis, so no fixation was used twice. After this coding, a ratio of fixations was calculated (coronal/(sagittal + coronal)) (see Fig. 7). A 3 × 4 (demonstrative × location) ANOVA was performed. There was no main effect for demonstrative, $F(2,30) = 0.15$, $MSE = 0.05$, $p = 0.86$, $\eta p^2 = 0.01$; "*this*" $M = 0.42$, $SE = 0.07$; "*that*" $M = 0.4$, $SE = 0.09$; "*the*" $M = 0.42$, $SE = 0.08$, nor location, $F(3,45) = 0.2.25$, $MSE = 0.16$, $p = 0.13$, $\eta p^2 = 0.13$, nor an interaction with distance, $F(6,90) = 0.78$, $MSE = 0.05$, $p = 0.59$, $\eta p^2 = 0.05$, suggesting that the language effect was not caused by differences in search-behavior. Based on these data, we cannot distinguish between different models for the use of reference frames in memory for object location.

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[2] This involves the manual coding of video-based eye-tracking data, by which fixations are coded on a gaze map.

[3] Although the coding was adjusted for the different distances, this does not detract from the results as the adjustments were conducted across the different language conditions.

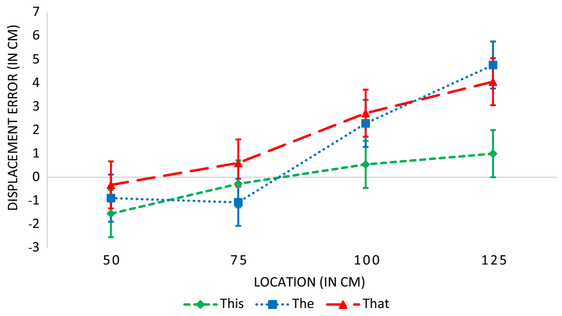

Fig. 7. Behavioral data of Experiment 3, error-bars are 95% confidence intervals.

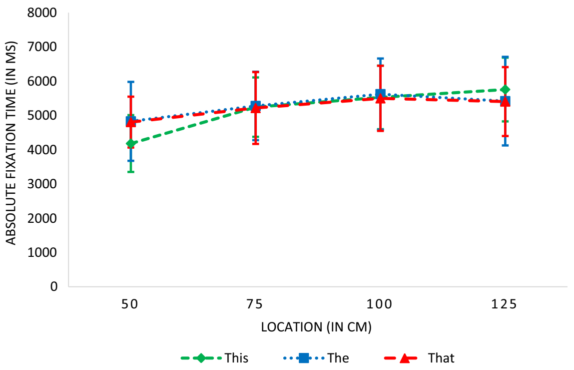

Fig. 8. Gaze data from Experiment 3, fixation time on the objects in the respective language condition at the respective locations averaged per trial (in ms). Error-bars are 95% confidence intervals.

5. General discussion

The results of all three experiments show that language affects memory for object location, with main effects of language in all three studies. The use of both demonstratives (Experiment 1 and 3) and possessives (Experiment 2) affects memory for object location. These results are consistent with previous studies showing an influence of language on memory for spatial relations (Feist & Gentner, 2007; Loewenstein & Gentner, 2005), and also with the effects of object knowledge on object location memory reported by Coventry et al. (2014). We have found robust effects of language on object location memory together with an effect of distance on memory for object location. We first consider explanations for these results prior to implications for theories of language and memory more generally.

Three possible accounts of the influence of language on object location memory were set out prior to designing the present series of experiments: the expectation account, the congruence account, and an attention allocation model. The difference between the expectation and congruence models is the prediction of an interaction in the latter, and a main effect of language without an interaction in the former. The expectation model, proposed by Coventry et al. (2014), to explain object knowledge effects on memory, maintains that language elicits an expectation about an objects' location which is concatenated with actual object location, leading to the prediction that the language effect should be the same for objects in near space and far space. In contrast, the congruence account predicts that memory should be better for trials in which language is congruent with the object location, predicting an interaction between language and location; congruent trials (where *this*/*that* are respectively combined with *near*/*far* space) should be remembered better than incongruent trials (in which *this*/*that* are respectively combined with *far*/*near* space). In Experiments 1 and 3, there was no interaction, supporting the expectation account. In Experiment 2 (possessives), there was an interaction, but this effect was driven by the absence of a location effect for the *my* condition and not by congruence/incongruence contrasts. Thus, as a whole, results of the current experiments all support the expectation model.

Experiment 3 tested the third possibility that different types of language might result in different amounts of attention being paid to objects/locations, with associated differences in memory performance. Put simply, the longer one spends looking at an object, the better one's memory for object location. The eye tracking data from this experiment revealed no differences in viewing time as a function of demonstrative. Also, participants did not present different searching behavior based on different demonstratives, allowing us to rule out the attention allocation model.

Given that the results support the expectation model, there are three keys issues that merit discussion. First, we can consider the relationship between the expectation model and memory models more broadly. Memory for object location is often taken to involve memory for the location in which an object is positioned, memory for the object itself, and a binding between object location and object (see for example Postma & De Haan, 1996). Previously, Coventry et al. (2014), finding effects of object knowledge on memory for object location, argued against memory models that prioritize object location over object knowledge (e.g. the model of Jiang, Olson, & Chun, 2000, who argued that location may act as an anchor to which object properties are attached). However, the effects of language on memory for object location and the previous effects of object knowledge reported are consistent with variants of *object file* theory (Kahneman & Treisman, 1984), in which object location is one of the features integrated in the file. Location features appear not to be bound to an absolute location but are defined relative to an abstract representation, which leads to memory errors (see Hollingworth & Rasmussen, 2010; Pertzov, Dong, Peich, & Husain, 2012). This focus on relative location can explain how spatial language can cue memory for object location, via the expectation of the objects' location relative to the speaker or another object. Wang and Spelke (2002) suggested that the human representational system depends in some way on language, by which humans can go beyond the limits of orientation systems as found in animals. This influence of language skills may facilitate more flexible problem solving (Hermer-Vazquez, Moffet, & Munkholm, 2001). One can speculate that the advantage is that such a relative, dynamic system enables us to mentally process arrays in different contexts (e.g. a desk or the universe), using the same language and concepts.

Second, one needs to unpack in more detail how the expectation model works, and in particular, how the expectation values form and how they combine with the actual distance information available. Coventry et al. (2014) do not offer detail regarding this, but they assume that the expectation model works via the prediction of object location as a product of the history and context of past bindings between language, objects and location. For example, objects owned by people are more likely to be near people than equivalent objects owned by someone else. This likelihood is then used to predict future encounters with objects: if an object is owned, one would anticipate the object is nearer than if one does not own the object. This anticipation works similarly for the visibility and familiarity parameters Coventry et al. (2014) identified. Respectively, visible objects are usually closer than objects one cannot see, and familiar objects are more likely to be near us than unfamiliar objects. This anticipation-mechanism could be accommodated by correlational learning (see Pulvermüller, 2012) - the process in which neurons that fire together strengthen their connections and become more tightly associated (also known as potentiation), and such a mechanism has been implicated not only in mapping language to perception (Coventry et al., 2013), but also how one learns how words co-occur to form meaningful language structures during language learning (Saffran, 2002; Saffran, Aslin, & Newport, 1996).

The Expectation Model can also be extended outside spatial language, both in cases where language is explicit during a task (as in our studies), but also in cases where language may not be explicit, but may nevertheless affect non-linguistic performance. For example evidence from color perception (Bruner, Postman, & Rodrigues, 1951; Delk & Fillenbaum, 1965) has shown similar effects of the influence of object knowledge on memory. Object knowledge influences categorization of objects, so that participants judge objects within a category to have a more similar hue than objects between categories. For example, in an array of letters and numbers, participants judged symbols within a respective category to be more similar in color than between categories, even if the two, between categories, target symbols were identically colored (Goldstone, 1995). In another series of studies, it was shown that color memory and color perception judgements are influenced by the characteristic color of an object and these object knowledge effects were stronger in objects with a high color diagnosticity (e.g. yellow for a banana) than in objects with low color diagnosticity (yellow for a lamp) (Belli, 1988; Bruner et al., 1951; Hansen, Olkkonen, Walter, & Gegenfurtner, 2006; Tanaka & Presnell, 1999). These 'top down' effects on color perception are consistent with the idea that knowledge of expected hue combines with actual hue information leading to categorization errors. Such an account merits further testing in this domain.

More broadly the Expectation Model is consistent with models of predictive coding (Clark, 2013; Friston, 2005). Clark (2013) suggests that people use prediction to minimize energy costs (the free-energy principle, Friston, 2009). In this model, the brain receives input from the perceptual system and uses existing knowledge to *predict* or anticipate the new state of the world based on that perceptual input (Clark, 2013; Friston, 2003). The brain prepares a response based on this prediction and only needs to process the *error signal*, the difference between the prediction and the updated visual input, once the new state of the world emerges. This means that instead of processing or 'creating' a full response, the brain only needs to adjust the predicted response to be appropriate to the actual input. In the Expectation Model, the prediction is based upon learned associations between language, objects, and locations (for example via statistical/correlational learning), these associations can then reduce the work needed to process continually changing object location bindings on a moment to moment basis.

A third issue that needs discussion is whether the effects of language operate at the level of encoding or retrieval. One possibility is that *this*, for example, actually activates peripersonal space more when looking at an object than *that*, and therefore that the memory differences are a direct result of differences in peripersonal space activation during encoding. Such a view is consistent with recent models of perception (e.g., Bar, 2009) that incorporate top-down predictions from memory as a mechanism during the act of perceiving. Alternatively, it is possible that the influence of language only occurs at retrieval, with remembered distances migrating in the direction of the remembered demonstrative/possessive. In order to test between these alternatives, it is possible to run neuroimaging studies to measure the degree of peripersonal space activation while viewing objects under different object knowledge and/or language conditions (see Coventry et al., 2014 for discussion). A second way one can get at this issue relates to memory decay: if the influence of language operates at retrieval, then the longer the time interval the greater the effects of language there should be. We are currently exploring these possibilities.

In summary, we found a main effect of language (demonstratives and possessives) on memory for object location across experiments. We teased apart the predictions of three different models explaining this mechanism: the Expectation model, the Congruence model, and the Attention allocation model. Overall, results favored the Expectation model, suggesting that the expected location of an object – cued by language (e.g., *this* for referents close by; *that* for referents further away) – and the actual location are combined, leading to (mis)memory for object location.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.cognition.2016.04.016.

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