

**Executive and social-cognitive determinants of environmental dependency
syndrome in behavioural frontotemporal dementia**

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Abstract

Objective: Environmental dependency syndrome (EDS), including utilisation (UB) and imitation (IB) behaviours, is often reported in behavioural variant frontotemporal dementia (bvFTD). These behaviours are commonly attributed to executive dysfunction. However, inconsistent associations between EDS and poor executive performance has led to an alternative “social hypothesis”, instead implicating patients’ misinterpretation of the examiner’s intention. We investigated the possible explanatory cognitive mechanisms of EDS in bvFTD by relating UB and IB to performance on tests of executive functioning and theory of mind (ToM). **Method:** This study analysed retrospective data of 32 bvFTD patients. Data included scores of UB and IB, various executive measures, and ToM assessment using the faux pas test, from which we extracted a mental attribution score. **Results:** Of the patients, 15.6% and 40.6% exhibited UB and IB, respectively. We conducted an automatic linear modelling analysis with executive and mental attribution measures as predictor variables and UB and IB sequentially considered as target variables. ToM mental attribution score, visual abstraction and flexibility measures from Wisconsin Card Sorting Test and motor sequence performance significantly (corrected p 's<.05) predicted IB. No executive or ToM measures significantly predicted UB. **Conclusions:** These findings reveal a complex interaction between executive dysfunction and mental attribution deficits influencing the prevalence of EDS in bvFTD. Further investigation is required to improve our understanding of the mechanisms underlying these behaviours.

Keywords: bvFTD, imitation behaviour, utilisation behaviour, social hypothesis, Supervisory Attentional System

Public significance: Environmental-dependency syndrome (EDS) is a group of pathological behaviours that have been reported after frontal lesion/degeneration. Typically, patients use objects without having been asked to do so or imitate an examiner’s gestures during a clinical examination. The reasons for the presence of such behaviours are poorly understood and this study aimed to understand their cognitive origin, and whether EDS could be attributed to disinhibition or to a failure to infer the examiner’s expectations.

Introduction

Utilisation (UB) and imitation behaviours (IB) are the most commonly reported signs of an environmental dependency syndrome (EDS), such that they are complex motor sequences elicited by external stimuli (Lhermitte, 1983). In more detail, UB is defined as the tendency for patients to seize and use familiar objects in an irrelevant context, while IB refers to when patients mimic gestures performed by the examiner (Lhermitte, Pillon, & Serdaru, 1986). Both UB and IB occur without instruction and often persist or reoccur after the examiner gives direct instruction to stop. These behaviours were first observed in patients with frontal lesions (Lhermitte, 1983) and as such are considered characteristic of frontal or fronto-striatal dysfunction, which was later confirmed (De Renzi, Cavalleri, & Facchini, 1996; Eslinger, Warner, Grattan, & Easton, 1991; Fukui, Hasegawa, Sugita, & Tsukagoshi, 1993; Shallice, Burgess, Schon, & Baxter, 1989). UB and IB have since been reported in neurodegenerative conditions such as frontotemporal dementia (FTD) (Ghosh & Dutt, 2010), particularly its behavioural variant (bvFTD) (Ghosh, Dutt, Bhargava, & Snowden, 2013; Grossi, De Lucia, Milan, & Trojano, 2015) which is characterized by a marked brain atrophy involving frontal regions and fronto-striatal networks (Bertoux, O'Callaghan, Flanagan, Hodges, & Hornberger, 2015).

Resulting from the association between EDS and compromised frontal lobe functioning, the Supervisory Attentional System model proposed by Norman and Shallice (Norman & Shallice, 1980) emerged as the dominant explanatory hypothesis for EDS. According to this model, EDS results from the ineffective inhibition by higher-level executive process of the activation and enactment of learned motor sequences that are elicited by environmental stimuli, such as a familiar object or a gesture (Blakemore, Wolpert, & Frith, 2002; Frith, Blakemore & Wolpert, 2000). As such, UB and IB are expected to arise in the context of executive impairment with relatively preserved visuospatial functioning. However, this model was mainly based on the exploration of EDS in patients with focal frontal lesions and the specific link between UB and IB and a dysexecutive syndrome has been sparsely investigated so far. The neuropsychological underpinnings of EDS, specifically executive function, have only been investigated recently. In particular, a study by Besnard and colleagues (Besnard et al., 2011) demonstrated that UB and IB poorly correlated with executive dysfunction, therefore calling into question the applicability of the Supervisory

Attentional System model to EDS. These findings were supported by those from a recent study investigating UB and IB in bvFTD, which found that executive measures only correlated weakly with EDS behaviours (Ghosh et al., 2013). Studies conducted on frontal lesion patients also yielded contradictory results although IB and UB were only observed in a negligible percentage of their samples, therefore complicating the interpretation of these findings (Brazzelli, Colombo, Della Sala, & Spinnler, 1994; De Renzi et al., 1996). In this context, Besnard and colleagues argued that although the Supervisory Attentional System model might provide an appropriate framework to explain the activation of a well-learned motor sequence, such as with UB, it did not adequately explain other environmentally dependent behaviours that may not have been previously learned, as could be the case for IB (Besnard et al., 2011). As a result, they proposed an alternative ‘social hypothesis’ that EDS symptoms could instead be underpinned by the patient’s misinterpretation of the examiner’s intentions, possibly mediated by theory of mind (ToM) deficits. According to this hypothesis, patients misinterpret that the presentation of an object or gesture by the examiner as an indication that the examiner requires a response. Following this, two studies involving small groups of frontal lesion cases were conducted (Besnard et al., 2016a; Besnard J. et al., 2016b). In both studies, no correlation was found between EDS and executive performance as well as ToM measures. This absence of association between EDS and ToM was attributed to the nature of the ToM task employed, which relied on the attribution of intentions without involving any social interaction and evaluation of social knowledge. This social contextual element could be indeed crucially relevant to the social hypothesis of EDS, which posits that these behaviours arise from poor mental attribution within the context of social interaction between patient and examiner.

By contrast, in this study, we aim to investigate the relationship between EDS and executive/attentional impairment as well as mental attribution ability on a test of social faux pas in a group of patients with behavioural variant of frontotemporal dementia (bvFTD). The behavioural variant of frontotemporal dementia (bvFTD) provides an ideal population to evaluate these two hypotheses due to these patients’ characteristic marked executive (Rascovsky et al., 2011) and social cognition deficits (Bertoux, et al., 2016a; Elamin, Pender, Hardiman, & Abrahams, 2012), including pronounced ToM impairment (Bertoux et al., 2012; Torralva et al., 2007). No study to

our knowledge has directly investigated and contrasted the Supervisory Attentional System model and the social hypothesis in the same sample by applying a measure of mental attribution dependent on social interaction knowledge. We aimed to address this by relating the occurrence of the most common symptoms of EDS, namely UB and IB, to performance on a range of tests assessing executive functioning and ToM, including a novel mental attribution score. Additionally, instead of using a classical statistical approach such as correlations or analyses of variances, we used an automated linear model to more accurately determine the respective contributions of these cognitive processes to the prevalence of these abnormal behaviours.

Methods

Participants

We selected 32 bvFTD patients from the database of the Memory and Language Unit, Saint-Anne Hospital (Paris, France) between September 2013 and January 2016. Patients were selected if they received a clinical diagnosis of bvFTD and had complete demographic and neuropsychological data relevant to this study completed during the same clinical visit. The diagnosis was made after a multi-disciplinary consultation with a team involving neurological and neuropsychological assessments. All patients (1) presented with prominent changes in personality and social behaviour according to the core clinical diagnostic criteria for probable bvFTD (Rascovsky et al., 2011); (2) were followed-up over at least 24 months to ensure that the clinical progression was consistent with the diagnosis of bvFTD (to exclude non-progressive phenocopy cases (Kipps, Hodges, & Hornberger, 2010)); (3) underwent magnetic resonance imaging (MRI) and/or single photon emission computed tomography (SPECT), showing respectively a frontal/fronto-temporal atrophy or hypoperfusion. We included patients with memory impairment if the patient met the other core diagnostic criteria for probable bvFTD (Bertoux et al., 2014). Finally, a lumbar puncture was administered to 11 of the patients, mostly in amnesic cases where the distinction between bvFTD and AD was unclear, showing for all of them a non-Alzheimer cerebro-spinal fluid (CSF) biomarkers profile, therefore excluding the possibility of atypical frontal Alzheimer's disease. Exclusion criteria for this study were (1) clinical or neuroimaging evidence of focal lesions, (2) severe cortical or

subcortical vascular lesions on brain MRI, (3) severe depression or other psychiatric condition such as bipolar disorder or schizophrenia, or (4) motor neuron disease. Biological and clinical data of all patients were generated during routine clinical workup and were retrospectively extracted for the purpose of this study. As per French legislation, explicit informed consent was waived as patients and their relatives were informed that individual data might be used in retrospective clinical research studies.

Neuropsychological assessment

Each patient underwent a comprehensive neuropsychological examination. Overall cognitive performance was measured using the Mini Mental State Examination (MMSE; maximum score 30) (Folstein, 2001) and the Mattis Dementia Rating Scale (MDRS; maximum score 144) (Mattis, 1976) assessing general efficiency. Executive and working memory/attention measures included semantic and lexical verbal fluency tests, forward and backward digit spans as well as the Frontal Assessment Battery (FAB; maximum score 18) (Dubois, Slachevsky, Litvan, & Pillon, 2000) and the modified Wisconsin Card Sorting Test (WCST) (Nelson, 1976). Notably, we included in the analyses the four following FAB subscores: similarities, Luria's motor sequences, conflicting instructions and go/no-go, and the three following WCST scores: number of categories identified and successfully maintained, number of perseverative errors, number of attentional errors.

ToM was assessed using the reduced and modified faux pas test (maximum score 15) from the mini Social cognition and Emotional Assessment (mini-SEA) (Bertoux et al., 2012). Briefly, patients have to read short stories and to detect the presence of a faux pas. After its correct detection, they have to answer questions assessing its identification, knowledge, intentionality, and emotional impact on the victim (empathy). As a novelty, we defined a mental attribution score by adding the scores assessing Intentionality and Empathy (maximum score 2).

Evaluation of ED

UB and IB were evaluated using standardized procedures extensively described in a previous work (Lagarde et al., 2013). The method we used was closer to the

'incidental' method of measuring UB, following the distinction between 'induced' and 'incidental' UB proposed by Shallice et al. (Shallice et al., 1989). To summarize, UB was assessed throughout the examination when the patient was engaged in other tasks (for example, during a clinical interview). Objects (such as a pencil, a piece of paper, a mobile phone, etc.) were, one at a time, successively put on the desk within the patient's reach without any comment or instructions from the clinician. UB occurred if the patient used an object after being instructed not to do so. To assess IB, the clinician, again without providing instructions, performed different gestures as previously described by Lhermitte et al. (Lhermitte et al., 1986a): clapping hands, slapping his/her thighs with both hands at the same time and executing a military salute. If the patient imitated the gestures spontaneously, the clinician told him/her not to do so, and then repeated the gestures one more time.

The presence of each of the two behaviours (UB, IB) was initially rated by clinicians according to the original rating scale outlined by Lhermitte and colleagues (Lhermitte et al., 1986a) ranging from 0 to 4. The two higher scores indicated the absence of IB with either the patient questioning the clinician in order to know if he/she has to imitate (score of 3) or no hesitation and no behaviour at all (score of 4). We chose to transpose Lhermitte et al.'s original scale into a 0 to 3 rating scale, but contrary to previous studies, our scoring collapses these last two scores (which should be considered as normal scores as they reflect normal behaviour) and retains the lower scores. Scoring of IB and UB was therefore: 3/3 for no abnormal behaviour 2/3 when patients performed the abnormal behaviour but stopped when the clinician asked them not to do so; 1/3 when patients performed the abnormal behaviour, stopped when the clinician asked but continued to imitate/utilize after a short interfering period; 0/3 when patients performed the abnormal behaviour and did not stop it even after the clinician asked them to stop.

Statistical analyses

All analyses were performed using IBM SPSS Statistics, Version 23.0. The automatic linear modelling (LINEAR) procedure was used to identify the neuropsychological predictors of each EDS behaviour. This procedure overcomes several limitations of a standard linear regression procedure by implementing an

automatic data preparation and subset selection method. In particular, it can compute all-possible-subsets regression of potential predictors rather than only stepwise regression, which allows for the best subset of variables to be determined and therefore a more precise detection of relevant predictors. For all significant predictors, the predictor importance indicates the relative importance of each predictor in estimating the model. In SPSS, the residual sum of squares is employed to compute this value, generated from the squared semi-partial correlations. The sum of these relative values should be equal to 1. Sequential Holm-Bonferroni corrections for multiple comparisons were applied to the resulting model. Non-parametric spearman rank correlation was used to relate UB to IB and mental attribution to executive functioning (EF) measures due to the non-normal distributions of these variables, with Bonferroni corrections.

Results

Demographics and clinical data

Patients had a mean age of 63 year (SD = 8.84), education of 10.93 years (SD = 3.62), and 21 of the patients were male. The mean disease duration since first symptoms was 3.18 years (SD = 2.55). Both MMSE (M = 24.27, SD = 3.69) and MDRS (M = 124.46, SD = 12.85) scores indicated that patients were in early and mild stages of the disease.

Prevalence of environmental dependency behaviours in bvFTD

Of the patients, 15.6% (n=5) exhibited UB, defined by a score $<3/3$. Specifically, 12.5% (n=4) exhibited UB but stopped when instructed to (score=2/3), and 3.1% (n=1) exhibited this behaviour, stopped when asked to, and then exhibited it after a short interfering period (score=1/3).

For IB, 40.6% (n=13) of the patients exhibited the behaviour, defined by a score $<3/3$. In more detail, 15.6% (n=5) imitated but did stop when asked not to continue the behaviour (score=2/3), and 25% (n=8) of patients imitated and continued to do so after a short interfering period (score=1/3).

In the whole sample, 9.4% of the patients (n=3) exhibited both IB and UB, and 46.9% (n=15) showed at least one ED behaviour. A Spearman rank correlation analysis conducted between both behavioural scores (IB and UB) was non-significant ($r=.09$ and $p=.61$).

Relationship between EF measures and mental attribution score

There were no significant correlations between mental attribution and EF measures (p 's > .05).

Cognitive predictors of ED symptoms in bvFTD

The automatic linear modelling analysis failed to identify any cognitive variables that significantly predicted UB. As only 15.6% of bvFTD patients (n=5) exhibited UB, the variance of this score may not have been sufficient to detect significant predictors in this small sample size.

The automatic linear modelling analysis for IB showed that it was significantly predicted ($R^2=.64$) by the WCST category score, perseveration errors and attentional errors, as well as the Mini-SEA mental attribution score, and the FAB Luria motor sequence score. Results are presented in Table 1. After applying a Holm-Bonferroni correction, the attentional errors of the WCST lost significance as a predictor but the mental attribution score, WCST perseveration errors, category score and FAB Luria motor sequence score remained significantly significant predictors of IB.

Interestingly, the WCST category score had the highest importance value (0.410), suggesting that it is the most important predictor of the model.

(Please insert Table 1 around here)

Discussion

This study aimed to investigate and compare the two predominant theories explaining EDS, namely the Supervisory Attentional System and social hypothesis models. Using an original statistical approach based on automated linear modelling in a well-characterized group of bvFTD patients, with frontal involvement causing both executive and social cognition deficits, our results indicate that impairments of both executive functioning and ToM appear to contribute to EDS, and more specifically IB, suggesting a more complex interaction between cognitive mechanisms than previously suggested.

When considering all cognitive variables included in the automated linear model, this study showed that processes dependent on executive functioning including visual abstraction impairment, cognitive inhibition deficit, decreased attention and motor sequence dysfunctions were all identified as significant predictors of IB. However, the results also showed that impaired mental attribution abilities could also relate to this behaviour, as it significantly predicted its presence. Taken altogether, our findings show for the first time that both executive and mental attribution dysfunctions could explain IB, suggesting a complex picture of mechanisms relating to this abnormal behaviour. These findings have significant theoretical consequence and, although they are preliminary, lend support to both the classic hypothesis that EDS behaviours stem from ineffective executive control over externally-stimulated activity (S.-J. Blakemore, D. M. Wolpert, & C. D. Frith, 2002; C. D. Frith, S. Blakemore, & D. M. Wolpert, 2000) as well as the recently proposed ‘social hypothesis’ (Besnard et al., 2011), which considers that EDS arises from a misinterpretation of the examiner’s intentions.

It is of interest to consider that, in his seminal observations, Lhermitte noted that EDS behaviours can often reflect a dependency towards a social context, and posited therefore that the true dimension of IB and UB is *social* (Lhermitte, 1986b). This present study is the first to provide empirical results that could support the social hypothesis of EDS, or, in another words, that EDS could arise from a failed attribution of the examiner’s intentions within the social context of the clinical examination. The two studies having previously directly assessed the social interpretation of EDS have indeed failed to provide any results in its favour (Besnard et al, 2016a; 2016b). In the first study, only 4 patients of the case series exhibited EDS, of which only one showed a ToM deficit, which was insufficient to establish

any statistical association. In the second study, the important overlap between patients and controls in the ToM tasks revealed that only a handful of frontal patients actually exhibited a ToM impairment, which should have drastically limited the investigation of its link with EDS. Another explanation of such diverging results with our study is the nature of the ToM tasks that were used in Besnard and colleagues' studies. Indeed, the Character Intention Task (Brunet, Sarfati, Hardy-Baylé & Decety, 2000) and the Reading the Mind in the Eyes Test (Baron-Cohen, Jolliffe, Mortimore & Robertson, 1997) do not involve any context of social interaction or social knowledge assessment by contrast to the measure we used to assess mental attribution. In more detail, the Character Intention Task involves the choice, among three proposed drawings, of the one that complete a story depicted by three previous cartoons. In this story, a character's behaviour is initiated (e.g. sawing prisons bars) and has to be continued by choosing a last drawing either depicting an action that would be compatible with the character's initial intention (e.g. making a rope out of clothes) or not compatible (e.g. sleeping or yelling). The Reading the Mind in the Eyes Test requires the subject to choose, among four verbal labels, the correct label corresponding to the affective state of images showing the eye region of the face. Neither the first nor the second task involve any social context or social interaction, by contrast to the faux pas test where short stories depict interactions between several characters, and the inference of intention is required in order to detect and understand the faux pas. Although we acknowledge that, in this last test, patients do not actively participate in these interactions, but rather are spectators, we believe that our measure of mental attribution is more appropriate to test the social hypothesis in the EDS field, as it is a direct measure of mental attribution in a context of social interaction, by contrast to measures previously used. Further studies should directly and explicitly investigate mental attribution during EDS evaluation.

Among all the cognitive variables that were entered into the automated linear model, those tapping into abstract reasoning, cognitive inhibition, attentional and motor sequencing abilities as well as mental attribution capacity were the significant predictors of IB. Visual abstract reasoning difficulties, as assessed by the WCST, could relate to poor deductive reasoning by the patient of what should be done or not during the incidental assessment of IB. The relationship between IB and cognitive disinhibition, as reflected by WCST perseverative errors, could lend partial support to

the Supervisory Attentional System model of EDS arising from an inability to regulate behaviour elicited by external stimuli, particularly after that stimulus is no longer contextually relevant. In addition, it should be noted that the data of our study were extracted from a clinical neuropsychological assessment in which the patients have been previously reinforced to imitate some of the clinician's gestures or to repeat words, through the evaluation of praxis and language. Although we lack data to support this assumption, it could be hypothesised that, stuck within a positively reinforced behaviour of imitation, favoured by some attentional disturbances (although this variable failed to reach significance after correction for multiple comparisons) and impairment of mental attribution abilities, the patients could have been more prone to imitate the examiner's actions in an ambiguous setting. As an extension to this hypothesis, one could assume that the rigid and directive framework of the neuropsychological or neurological evaluation, taking place into the intimidating context of a hospital clinic and encouraged by the clinician's dominant status (Freidson, 1970), could increase the likelihood of IB. A last result of particular note is the relationship between IB and difficulties to complete Luria's motor sequence, which in addition to being considered predominantly indicative of frontal impairment, is also partly dependent on patients' ability to imitate clinicians. However, imitation is not the ability assessed by this task as its scores instead reflect the ability to reproduce three gestures in the correct order and to maintain this pattern after the examiner has stopped presenting the sequence. We therefore believe that this observed statistical relationship could indicate more of a frontal contribution of the areas that match the voluntary motor programming of actions rather than being linked to imitation abilities.

An interesting point of discussion regarding the contribution of both executive and ToM performances to predict the prevalence of EDS is the specific link between these two former cognitive processes. Several authors consider indeed that ToM relies on executive functioning and could therefore be critically impaired due to executive dysfunction (Devine & Hughes, 2014). From this perspective, the mental attribution deficit predicting IB in our study could have been interpreted as an indirect consequence of a primary executive deficit. In other words, following this view, one could hypothesise that executive deficit would be the sole predictor of both IB and mental attribution impairment at the same time. Indeed, although previous group

findings (Bertoux, O'Callaghan, Dubois, & Hornberger, 2016) and clinical cases (Lough, Gregory, & Hodges, 2001) tend to support a relative independence between ToM and executive functioning performances in bvFTD, recent evidence suggests that mental attribution mechanisms, and not other ToM dimensions, could specifically rely on executive functions (Bertoux et al., 2016b; Le Bouc et al., 2012; Snowden et al., 2003). This link echoes the common view that one has to inhibit his or her own mental states in order to infer the mental state of others (Samson, Apperly, Kathirgamanathan, & Humphreys, 2005), which is supported by the interacting models of ToM processing (Samson, 2009; Stone & Gerrans, 2006). However, in the sole framework of our study, it appeared unlikely that executive deficits, and particularly cognitive disinhibition, have negatively impacted mental attribution abilities in bvFTD patients, thus leading to an IB, as no correlation was observed between mental attribution performances and any scores of executive functioning. This result is moreover in agreement with recent findings suggesting that the inhibitory mechanisms necessary to infer another's mental state could be specific to mental state attribution processes and independent from other executive processes (Samson, Houthuys, & Humphreys, 2015).

A large proportion of patients (40.6%) exhibited IB, which is in line with the previous active investigations of IB prevalence in bvFTD, ranging from 32% to 61% (Ghosh et al., 2013; Grossi et al., 2015; Lagarde et al., 2013; Shimomura & Mori, 1998). However, only \approx 16% of patients exhibited UB, a lower proportion than in several previous investigations where the prevalence of incidental UB in FTD ranged from 58% to 70% (Ghosh & Dutt, 2010; Ghosh et al., 2013; Grossi et al., 2015). One possible reason for this discrepancy is that the patients included in our study were in the very mild stages of disease, whereas in the studies by Ghosh and colleagues (2010; 2013), patients were at more severe stages, as indicated by much lower scores on screening tests and disease severity. Indeed, there appears to be a link in these studies between more advanced or fast-progressing bvFTD and the emergence of more prevalent UB. Furthermore, previous studies have shown that UB is less commonly detected under active investigation than IB in mild bvFTD, with UB being quite rare at this early disease stage compared to IB (Lagarde et al., 2013). It has further been demonstrated in bvFTD that while IB is better detected than UB via active assessment in the clinic (Ghosh et al., 2013; Shimomura & Mori, 1998), UB is

more commonly reported via other methods such as caregiver history (Ghosh & Dutt, 2010; Ghosh et al., 2013).

Regarding the prevalence of both behaviours in our study, another point of interest is that only a small percentage (9.4%) of the patients exhibited both IB and UB in this study. Furthermore, IB and UB scores were not correlated with each other. Previous works have discussed the difference in prevalence of UB and IB within the same sample (De Renzi et al., 1969; Lagarde et al., 2013) and found the same pattern, with UB being rarely observed. We believe that this difference of prevalence or variance between the scores suggests that the two behaviours may relate to deficits in different processes. In line with this discrepancy between IB and UB, previous evidence has suggested that IB could be more dependent on processes underlying social control and self/other distinction by contrast to UB (Brass, Derrfuss, & von Cramon, 2005; Brass, Ruby, & Spengler, 2009; Spengler, von Cramon, & Brass, 2009). Taken together, these findings question the coherence of EDS as a clinical syndrome and suggest that IB and UB are in fact different phenomena, in line with previous works suggesting that these behaviours rely on distinct neural mechanisms (Rizzolatti, Fabbri-Destro, & Cattaneo, 2009).

Among the limitations of this study, we believe that despite the good sample size in this study, a larger sample size could have allowed a better detection of the mechanisms relating to EDS - especially UB, due to its rarity in this sample. Indeed, any assertions regarding EDS and its relationship to impairment in executive and ToM processes in our study can only be based on the findings for IB, as no significant predictors were found for UB. This is likely due to the small proportion of patients exhibiting this behaviour, which provided insufficient variance to detect significant predictors. Future studies with larger sample size could therefore yield enough variance to detect predictors of this behaviour. In particular, future studies should focus on context processing, which is known to be impaired in frontal patients (O'Callaghan et al., 2016), as context seems to be a critical dimension of EDS' expression. In addition, a question remains to determine whether abnormal behaviours such as IB or UB truly reveal, as Lhermitte suggested (1986), a more general dependency towards the environment in daily activities. Although examples related by bvFTD patients' carers during clinical interviews tend to support this idea, as well as patient's carer interviews (Gosh et al., 2013), the validity of EDS outside the clinic

should be assessed in a more systematic way in future studies to highlight the clinical interest of screening for such abnormal behaviour.

In conclusion, novel findings from this study provide support for a complex interaction of mechanisms relating to some EDS symptoms in bvFTD, with results suggesting a critical implication of both executive and social cognitive processes. As such, these preliminary results tend to support both the “social hypothesis” (Besnard et al., 2011) and the classical Supervisory Attentional System model positing that EDS is driven by compromised executive function (Norman & Shallice, 1980).

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	M (SD)	B coefficient	Std. Error	t	Sig.	95% CI	Importance
WCST							
Categories	3.53 (1.98)	0.539	0.09	5.85	<.0001*	0.35 – 0.73	0.410
Perseveration errors	7.16 (6.78)	0.105	0.02	4.37	<.0001*	0.06 – 0.15	0.230
Attentional errors	1.72 (2.03)	0.284	0.11	2.69	.012	0.07 – 0.50	0.087
Verbal fluency							
Semantic fluency	14.34 (7.43)				/		
Lexical Fluency	8.59 (6.34)				/		
FAB							
Similarities	2.26 (.77)				/		
Luria motor sequence	2.32 (.87)	-1.702	0.47	-3.60	.001*	-2.68 – -0.73	0.169
Conflicting instructions	2.65 (.84)				/		
Go No-Go	2.29 (.97)				/		
Digit Spans							
Forward	5.03 (1.09)				/		
Backward	3.38 (1.01)				/		
Mini-SEA Faux-pas							
Mental attribution	3.92 (2.75)	-1.249	0.42	-2.95	.007*	-2.12 – -0.38	0.104

Table 1. Results of the Automated Linear Modelling assessing the predictors of imitation behaviour with Means (M) and Standard deviations (SD). For the variables retained in the model: unstandardized beta coefficient, standardized error, t values, significance, 95% confidence interval (lower, upper) and importance.

*=values passing the significance threshold corrected for Holm-Bonferroni multiple comparison.

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