OXFORD
UNIVERSITY PRESS

Archives of Clinical Neuropsychology 00 (2020) 1–10

Archives of CLINICAL NEUROPSYCHOLOGY

Self-Awareness Moderates the Association Between Executive Dysfunction and Functional Independence After Acquired Brain Injury

Dolores Villalobos[1,2,7], José M. Caperos[3,4], Álvaro Bilbao[5], Umberto Bivona[6], Rita Formisano[6], Javier Pacios[2,7,*]

[1] *Department of Psychology, Faculty of Health Sciences, Camilo José Cela University, Villafranca del Castillo, Madrid, Spain*
[2] *Laboratory of Cognitive and Computational Neuroscience, Center for Biomedical Technology, Technical University of Madrid, Complutense University of Madrid, Madrid, Spain*
[3] *Fundación San Juan de Dios, Madrid, Spain*
[4] *Departamento de Psicología, Universidad Pontificia Comillas, Madrid, Spain*
[5] *Centro de Referencia Estatal de Atención al Daño Cerebral (CEADAC), Madrid, Spain*
[6] *Istituto di Ricovero e Cura a Carattere Scientifico, Santa Lucia Foundation, Rome, Italy*
[7] *Department of Experimental Psychology, School of Psychology, Complutense University, Madrid, Spain*

*Corresponding author at: Department of Experimental Psychology, School of Psychology, Complutense University of Madrid, Campus de Somosaguas, Ctra. de Húmera, s/n, 28223 Pozuelo de Alarcón, 28040 Madrid, Spain. Tel.: (+34) 91 394 2778; fax: +34 91 394 3189. *E-mail address:* javier.pacios@ucm.es (J. Pacios).

Received 10 March 2020; revised 15 May 2020; Accepted 19 June 2020

Abstract

Objective: Impaired self-awareness (SA) is a common symptom after suffering acquired brain injury (ABI) which interferes with patient's rehabilitation and their functional independence. SA is associated with executive function and declarative memory, two cognitive functions that are related to participants' daily living functionality. Through this observational study, we aim to explore whether SA may play a moderator role in the relation between these two cognitive processes and functional independence.
Method: A sample of 69 participants with ABI completed a neuropsychological assessment focused on executive function and declarative memory which also included a measure of SA and functional independence. Two separated linear models were performed including functional independence, SA, and two neuropsychological factors (declarative memory and executive function) derived from a previous principal component analysis.
Results: Moderation analysis show a significant interaction between SA and executive function, reflecting an association between lower executive functioning and poorer functional outcome, only in participants with low levels of SA. Notwithstanding, declarative memory do not show a significant interaction with SA, even though higher declarative memory scores were associated with better functional independence.
Conclusions: SA seems to play a moderator effect between executive function, but not declarative memory, and functional independence. Accordingly, participants with executive deficits and low levels of SA might benefit from receiving specific SA interventions in the first instance, which would in turn positively impact on their functional independence.

Keywords: Anosognosia; Brain damage; Executive function; Memory; Activities of daily living; Moderation analysis

Introduction

Acquired brain injury (ABI) is a leading cause of death and disability worldwide. It has been defined as damage to the brain that occurs after birth due to traumatic or non-traumatic causes (Giustini, Pistarini, & Pisoni, 2013). ABI may be further categorized with regard to severity into mild, moderate, or severe, according to the length of loss of consciousness, alteration of consciousness/mental state, or post-traumatic amnesia (O'Neil et al., 2013). Major consequences of severe

doi:10.1093/arclin/acaa048

ABI are mortality, presence of a variety of neurological illnesses and disability, and long-lasting functional impairment (Arciniegas & Wortzel, 2014; Ciurli, Formisano, Bivona, Cantagallo, & Angelelli, 2011; Wilson et al., 2017). Motor, cognitive, behavioral, and emotional consequences of ABI cause a strong impact in the patient and their family's daily living functioning. The extent of cognitive impairment, as well as the subsequent evolution of neurocognitive dysfunction, is thought to depend on a variety of injury related and premorbid factors (Svingos, Asken, Jaffee, Bauer, & Heaton, 2019). In the acute stage of ABI physiological alterations have the main influence on the patient's condition. Over time, psychological processes, such as coping styles, personality, and emotion regulation, become increasingly influential (van der Horn et al., 2019). The ABI consequences sometimes last many years after the injury, bringing to light the need for long-term, and intermittent support and guidance to participation in everyday life for these patients (Erikson, Karlsson, & Tham, 2016).

A major goal of clinical interventions in patients with ABI is to reinstate their level of functional independence as much as possible, which in turn increases the likelihood of patients to return to their work or academic activity (Hofgren, Esbjörnsson, & Sunnerhagen, 2010). Among the variety of cognitive impairments commonly associated with ABI, specific deficits in verbal fluency, declarative memory, and information processing seems to predict their ability to return to work, which is considered as a good measure of real-world disability (Zakzanis & Grimes, 2017), while executive function impairment predicts also others abilities as money management, driving and maintaining a residence (Perna, Loughan, & Talka, 2012). Similarly, declarative memory and executive functions independently predict functional independence in instrumental activities of daily living (ADL), in healthy elders, but also in stroke or patients with dementia (Overdorp, Kessels, Claassen, & Oosterman, 2016). In addition, recent research has shown that psychological aspects are also related to functional independence in patients with ABI. Self-efficacy predicts functional independence and may serve as a protective factor after ABI among mildly impaired individuals. However, among those with moderate or severe cognitive impairment, health self-efficacy does not predict functional independence, possibly due to deficits in self-awareness (SA) (Parker et al., 2018) (i.e., the ability to be aware of one's own thoughts, feelings, and mental states) (Keenan, Gallup, & Falk, 2003). SA is considered a metacognitive skill that allows the individual reflecting on the condition of the disease, its consequences and the implications of such deficits for daily functioning (Cheng & Man, 2006). Indeed, a recent research has provided evidence on the relationship between SA and functional independence in patients with ABI (Villalobos, Bilbao, López-Muñoz, & Pacios, 2019).

The metacognitive aspect of SA has led to investigate how it is related to other high-order cognitive processes, particularly executive functions, involved in the ability to monitor and control the information processing required for voluntary and goal-directed behavior (Tate et al., 2014). The level of SA and executive functions seems to be related in patients with traumatic brain injury (TBI) (Hart, Whyte, Kim, & Vaccaro, 2005). Similar results have been reported for key executive measures, such as cognitive flexibility, inhibition (Bivona et al., 2008, 2019; Ciurli et al., 2010), and abstract reasoning (Chiou, Carlson, Arnett, Cosentino, & Hillary, 2011). Other studies have found general executive functioning (Bogod, Mateer, & MacDonald, 2003) or specific executive processes like flexibility and inhibition (Noé et al., 2005), working memory (Morton & Barker, 2010), and verbal fluency (Zimmermann, Mograbi, Hermes-Pereira, Fonseca, & Prigatano, 2017), as significant predictors of SA. In addition, a few studies have shown that declarative memory also seems to be an important predictor of SA (Noé et al., 2005; Zimmermann et al., 2017). Interestingly, a very recent research from our group has shown that cognitive predictors of SA may vary along the rehabilitation process. While verbal fluency (a general measure of executive function) (Schwartz, Baldo, Graves, & Brugger, 2003) predicted SA both at admission and discharge of the rehabilitation process, inhibition and cognitive flexibility, as well as declarative memory, appeared as significant predictors of post-rehabilitation SA (Villalobos, Caperos, Bilbao, López-Muñoz, & Pacios, 2020b).

On the other hand, patients with ABI that are able to manage on instrumental ADL appear to have higher levels of SA than those whose skills are limited to basic ADL (Giles et al., 2019). Some studies have even shown that SA itself has an important impact in functional independence of patients with ABI, so those patients with higher levels of SA reach more favorable rehabilitation outcomes (Ownsworth & Clare, 2006). Specifically, SA level at discharge from rehabilitation is related to the amount of activities in which the patient is involved (Hartman-Maeir, Soroker, Oman, & Katz, 2003), to the level of functional independence in daily life activities (Fischer, Gauggel, & Trexler, 2004), as well as to the degree of employability of the patient at the end of the rehabilitation process, even 5 years or more after the onset of the brain injury (Kelley et al., 2014; Sherer et al., 2003). Furthermore, SA improvements associated with different intervention programs seems to correlate with daily living functionality enhancements following those interventions (Engel, Chui, Goverover, & Dawson, 2017) (see Villalobos et al., 2020 for a systematic review).

Altogether, evidence suggests a complex pattern of relationships among cognitive status, SA, and ADL functioning in patients with ABI. Although the role of executive and declarative memory functioning in reaching an adequate level of daily living functionality seems well established, complementary work also attributes to SA a major role in this critical goal of rehabilitation. Toglia & Kirk (2000) have highlighted the metacognitive aspect of SA and its critical role in contributing to an independent functioning after ABI. According to this view, metacognition would facilitate to adjust one's knowledge and beliefs about one's strengths and limitations that derives from brain lesion. On the other hand, metacognition would play a critical role in monitoring and regulating one's performance in a given activity. Discrepancies between actual performance and what one expects to do would promote the adjustment of performance and the selection of alternative strategies, which in turn derives in a further restructuration of one's knowledge and beliefs (Toglia & Kirk, 2000). This intermediate role of metacognition makes SA a potential candidate to play a moderator role between cognitive status, more specifically executive functions and declarative memory, and functional independence. Indeed, SA has already been identified as a moderator of the relationship between neuropsychological performance and a fundamental functional ability such as on-road driving (Griffen, Rapport, Bryer, Bieliauskas, & Burt, 2011). Thus, the aim of the present study was to explore whether SA may play a moderator role in the relation between cognitive status (mainly executive functions and declarative memory) and functional independence in participants with ABI.

Based on the reviewed literature, we expected that participants with lower levels of SA would show stronger relationships between cognitive status and functional independence than those with higher levels of SA. Specifically, lower scores in executive functions and declarative memory would be associated with lower levels of functional independence in participants with more severe SA deficit.

Method

Participants

Sixty-nine adults with ABI (44 men and 25 women), with a mean age of 42.9 years ($SD = 11.1$, ranging from 18 to 56 years), and a mean educational level of 12.6 years ($SD = 3.8$), consecutively admitted as residential or outpatient in the National Center for Brain Injury Treatment in Madrid, Spain, from January 2018 to July 2019. Their time since injury at the moment of assessment ranged from 148 to 586 days, with a mean of 359.2 days (SD = 102.4). Participants were recruited according to the following inclusion criteria: age older than 16; diagnosis of moderate or severe ABI based on Glasgow Coma Scale (GCS) (Teasdale & Jennett, 1974) score (i.e., ≤ 8) or, if not available, on the presence of important deficits and/or difficulties at motor, cognitive, behavioral, or emotional levels during their initial assessment; medical status: stable; absence of relevant speech disturbances; ability to actively participate in an integrative rehabilitation process.

The etiology of brain injury included TBI ($n = 17$), stroke ($n = 39$), brain tumor ($n = 6$), postanoxic encephalopathy ($n = 6$) and other causes (decompression sickness) ($n = 1$). Neuroanatomical evidence of injury (magnetic resonance imaging or computed tomography scan) was gathered from each participant and is presented in Supplementary Table 1. The local ethical committee approved the study and all participants gave their informed consent prior to participation.

Measures

Functional independence measurement. Lawton Instrumental ADI Scale (Lawton IADL), a common measure of functional independence in population with ABI (Cheng & Man, 2006; Man, Yip, Ko, Kwok, & Tsang, 2010; Parker et al., 2018), was used to measure the functional changes in participants with respect to instrumental ADL. The Lawton IADL (Lawton & Brody, 1969) was developed for measuring eight advanced ADL: abilities to use the telephone, to shop, to prepare food, to do housekeeping, to do laundry, to use modes of transportation, to handle finances, and responsibility for one's own medications. A summary score ranging from 0 (low function, dependent) to 8 (high function, independent) was assigned. The validity of the Lawton IADL has been tested by correlating it with other different functional scales (the physical classification, Waldman & Fryman, 1964, [$r = .40$, $p < .01$], Mental Status Questionnaire, Pteiffer, 1975, [$r = .48$, $p < .01$], the behavior and adjustment rating scales, Aumack, 1962, [$r = .36$, $p < .05$], and the Physical Self-Maintenance Scale, Lawton & Brody, 1969, [$r = .61$, $p < .01$]). Inter-rater reliability of the Lawton IADL scale has been established at 0.85 (Lawton & Brody, 1969).

SA measurement. To assess SA, we used an ad-hoc scale developed in a semi-structured interview format, which mainly considers the metacognitive aspect of SA (Toglia & Kirk, 2000). According to previous studies that have raised the importance of separately assessing the awareness of the deficits and the awareness of the functional implications of such deficits (Giacino & Cicerone, 1998), this scale consisted of three main areas of assessment: awareness of injury, awareness of deficit, and awareness of disability. The scale scores range from 0 to 30, with maximum score indicating full awareness of having sustained a brain injury, of its consequences and of the disability it causes. Although the scale has not yet been formally validated, it has been used in previous studies (Villalobos, Bilbao, Espejo, & García-Pacios, 2018; Villalobos et al., 2019) showing a high correlation with the scores provided by the Self-Awareness of Deficits Interview (SADI) (Fleming, Strong, & Ashton, 1996). This agreement with a standardized and recognized instrument for the assessment of SA suggests that the scale used in the study is able to provide a valid measure for SA in a sample of participants with ABI (Villalobos et al., 2018). Nevertheless, to further confirm a high correlation between the scale and the SADI in the current study, the latter was also administered during the assessment showing high significant correlation between them ($n = 69$; $r = -.914$; $p < .001$; note that, unlike SA scale, higher scores on the SADI reflect greater SA impairments).

Cognitive measurement. For the neuropsychological assessment, a battery containing the following declarative memory and executive function tests was administered to all participants in the study.

Hopkins Verbal Learning Test (HVLT): It consists of three free-recall trials of a 12-word, semantically categorized list, follow by delayed recall (20 min) and a yes/no recognition (Brandt & Benedict, 2001). Three measures from this test were taken into account: the sum of the three trials recall (total recall), the delayed recall and recognition.

Digit forward, backward, and sequencing span test (from the Wechsler Adult Intelligence Scale—Fourth Edition, WAIS-IV) (Wechsler, 2009). The first part provides a measure of attentional span while the second and third parts are considered related to working memory capacity.

Verbal fluency task: Phonemic (letters “f,” “a,” and “s”) and semantic (“animals”) verbal fluency. It is a traditional executive function measure related to flexibility and cognitive control processes (Lezak, Howieson, Bigler, & Tranel, 2012). We consider the total verbal fluency measure (phonemic + semantic).

Wisconsin Card Sorting Test (WCST) (Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) is one of the most widely used tests to assess executive functioning, specifically inhibition and cognitive flexibility. Specifically, we considered three measures from the WCST-64 version (Greve, 2003): number of categories completed, percentage of errors and percentage of perseverative responses.

Two principal components analyses were applied to reduce the amount of neuropsychological measures from 9 to 2, each of them representing a common factor of either declarative memory or executive function scores. This approach has been previously used to reduce dimensionality of neuropsychological data (Busch, McBride, Curtiss, & Vanderploeg, 2005; Gurrera, Moye, Karel, Azar, & Armesto, 2006; Sigurdardottir, Andelic, Roe, & Schanke, 2009). In both cases, the parallel analysis recommended a one factor structure; we used the regression method to estimate participants’ scores in the underlying factors, declarative memory, and executive function. In the case of declarative memory, the principal component’s analysis showed homogeneity among variables, the factor accounted for the 82.9% of the variance and presented high loads in all variables HVLT total recall (.93), HVLT delayed recall (.95), and HVLT recognition (.84). In the case of executive functions, the analysis revealed a less homogeneous structure although the factor accounted for the 57.8% of the variance, with also high weights in all variables digit backward (.69), digit sequencing (.68), verbal fluency (.69) and WCST number of categories completed (.83), % of errors (−.78) and % of perseverative responses (−.87). Digit forward were not taken into account in either analysis given that it rather reflects more an attentional span measure than an executive or declarative memory score.

Procedure

This was a prospective, observational study. All participants were assessed between 1 and 2 weeks before they finished their rehabilitation, at the discharging from the center. An experienced clinical neuropsychologist conducted the assessments and all tests were administered following the same order in all participants. Given the semi-structured interview format of the SA scale and that items are scored according to the clinician’s judgement, one may be concerned about the possibility that potential examiner bias could have affected this measure. Although relying on the clinician’s judgement is not exempt of certain degree of subjectivity, this approach is considered more precise than those that uses reports provided by the participant’s relatives, which is known to be affected by a high degree of subjectivity (Prigatano, Borgaro, Baker, & Wethe, 2005). Indeed, it is the approach implemented in the most recognized SA scales (Fleming et al., 1996). Notwithstanding, at the moment of the SA assessment, the clinician had not access to the composite measure derived from the regression analysis that were, in turn, the variables of interest in the study. Besides, the clinician did not know about the particular goals of the present study. Therefore, a potential examiner bias affecting the SA measure was very limited.

All participants performed the assessment successfully, though three participants were not able to complete the WCST. Accordingly, these participants were considered only in the analysis that did not include such variables.

Table 1. Differences between high and low self-awareness (SA) group in demographic, functional, SA and neuropsychological variables

Variable	High SA		Low SA		Test statistic[a]	*df*	*p*
	Mean	SD	Mean	SD			
Gender (Nr. males)[b]	19 (55.9%)		25 (71.4%)		1.80	1	.180
Age	42.1	10.9	43.6	11.4	-0.54	67	.590
Years of education	14.0	3.2	11.2	3.9	3.25	65.2	.002
Time since injury (days)	361.2	117.2	357.3	87.3	0.16	67	.876
Functional independence	6.0	2.0	4.0	2.67	3.46	63.3	<.001
Self-awareness	29.3	0.9	20.7	5.6	8.97	36	<.001
Hopkins Verbal Learning Test (HVLT) total recall	26.3	5.2	18.7	5.7	5.82	67	<.001
HVLT delayed recall	8.6	2.5	4.6	3.8	5.07	58.7	<.001
HVLT recognition	10.2	2.0	8.2	3.4	3.07	55.4	.003
Digit forward	9.1	1.8	8.1	1.7	2.39	67	.020
Digit backward	8.0	1.5	6.9	1.5	3.24	67	.002
Digit sequencing	8.0	1.7	6.7	1.5	3.25	67	.002
Verbal fluency	59.9	13.4	41.5	15.2	5.34	67	<.001
Wisconsin Card Sorting Test (WCST) number of categorizes completed	2.8	0.6	2.1	1.0	3.23	51.7	.002
WCST % of errors	20.5	11.0	32.2	18.9	-3.08	51.6	.003
WCST % of perseverative responses	12.2	8.4	24.7	18.9	-3.45	44.2	.001
Declarative memory common factor	0.54	0.71	-0.53	0.97	5.23	62.3	<.001
Executive function common factor	0.52	0.62	-0.52	1.05	4.86	51.6	<.001

[a]All the tests reported are Student *t* test except for the sex that is an X^2 test.
[b]In the case of gender, the frequency and the percentage of males is reported instead of the mean and the SD.

Statistical Analysis

To divide the sample in two different groups according to their level of SA, we employed the median split of SA score (26). Although a score 26 out of 30 may seem very close to the maximum, it is not likely that ceiling effects could have affected the SA measure. First, the scale explores the level of SA in three consecutive but not independent dimensions, so that scores above 20 do not reflect a high level of SA (see Villalobos et al., 2018 for a detailed description of the scale and scoring). Furthermore, the mean SA score for the low SA group (20.7) was far from the mean score for the high SA group (29.3) which reasonably reflects an adjusted SA level (see Table 1).

Descriptive statistics were used to illustrate the characteristics of each group: high and low SA. We used independent samples student's *t* and X^2 tests to explore differences between SA groups in demographics and neuropsychological variables, and Pearson correlation to explore relationship between neuropsychological and demographics ones.

Finally, in order to explore the role of SA as a potential moderator in the relationship between declarative memory and executive function with functional independence, we run two separated linear models including functional independence as dependent variable and the neuropsychological variable (declarative memory or executive function), SA and the interaction of both variables as predictors. We have also included in the analysis years of education and time since injury, as covariates, in order to account for possible confounds (Field, 2013). Continuous predictors in the regression analyses were centered, which reduce collinearity (Cohen, Cohen, West, & Aiken, 2013). Nevertheless, we also checked for collinearity in the moderation models, finding no VIF larger than 10 or tolerance fewer than .1 (Pardo Merino & San Martín, 2010) (maximum VIF = 6.02; minimum tolerance = .166). Data analysis were carried out using SPSS software (version 25) and Jamovi (version 1.1.6.0; 2019). In all the analyses, the confidence level was 95% and $p < .05$ values were considered significant.

Results

We did not find differences between high and low SA groups in the male/female ratio, neither in the mean age nor time elapsed since injury, although we did find that the high SA group had more years of education (14.0) than the low SA group (11.2), $t(65.2) = 3.25$, $p = .002$. We also found differences in functional independence and in the estimated neuropsychological factors (executive function and declarative memory), as well as in the underlying primary measures (Table 1).

Table 2. Relationship between demographic, functional independence, and neuropsychological variables

Variables		Functional independence	Declarative memory common factor	Executive function common factor
Age	*r*	-.090	.036	-.064
	p-value	.462	.769	.608
	N	69	69	66
Years of education	*r*	.221	.145	.489
	p-value	.067	.234	< .001
	N	69	69	66
Time since injury	*r*	-.245	-.134	-.214
	p-value	.043	.271	.085
	N	69	69	66
Executive function common factor	*r*	.465	.537	
	p-value	< .001	< .001	
	N	66	66	
Declarative memory common factor	*r*	.371		
	p-value	.002		
	N	69		

Table 3. Moderation regression models

Effect	Estimate	*SE*	95% CI	*β*	*df*	*t*	*p*
Intercept	5.29	0.33	4.63 to 5.95	.000	63	16.00	< .001
Time since injury	-0.01	0.00	−0.01 to 0.00	-.221	63	-2.02	.048
Education	0.08	0.08	−0.08 to 0.24	.116	63	1.00	.323
Self-awareness (SA)	-1.43	0.70	−2.84 to −0.03	-.560	63	-2.04	.046
Declarative memory	0.33	0.35	−0.37 to 1.03	.128	63	0.94	.351
SA × declarative memory	1.04	0.69	−0.35 to 2.42	.404	63	1.49	.140
Intercept	5.62	0.31	5.00 to 6.25	.000	60	18.00	< .001
Time since injury	0.00	0.00	−0.01 to 0.00	-.149	60	-1.36	.180
Education	-0.04	0.08	−0.19 to 0.12	-.055	60	-0.45	.654
SA	-1.57	0.63	−2.84 to −0.31	-.646	60	-2.48	.016
Executive function	0.41	0.39	−0.36 to 1.18	.170	60	1.08	.286
SA × executive function	1.65	0.70	0.26 to 3.05	.678	60	2.37	.021

Functional independence showed no relationship with age neither educational level, although is related to time elapsed since injury. As it was expected, we also found positive relationship between functionality and the neuropsychological factors (Table 2).

We did not find an interaction between declarative memory and SA, $F(1, 63) = 2.23$; $p = .140$; $\omega^2 = .014$, neither a relationship between declarative memory and functional Lawton test, $F(1, 63) = 0.88$; $p = .351$; $\omega^2 = .001$. Meanwhile participants with greater SA presented larger functioning, $F(1, 63) = 4.16$; $p = .046$; $\omega^2 = .036$, (see Table 3). Correlation analysis between functional independence and declarative memory in low SA group show a no-significant trend, $r = .331$; $p = .052$, although this relation did not appear in participants with high SA, $r = -.018$; $p = .920$ (Fig. 1A).

In the case of executive function, we found a significant interaction between SA and executive function, $F(1, 60) = 5.63$; $p = .021$; $\omega^2 = .051$ (see Table 3). In participants with low SA, the more the deficit in executive function the more the restriction in functional independence, $r = .513$; $p = .002$, but in participants with high SA these relationship does not appear, $r = -.099$; $p = .582$ (Fig. 1B).

Discussion

This study aimed to explore SA as a moderator factor of the relationship between cognitive processes (specifically declarative memory and executive functions) and functional independence in participants with ABI. Previous studies have identified cognitive process related to SA, especially executive functions (Bivona et al., 2019; Ciurli et al., 2010; Hart et al., 2005; Morton & Barker, 2010) and declarative memory (Noé et al., 2005; Zimmermann et al., 2017). Also, the relation between SA and functional independence has been described (Giles et al., 2019; Kelley et al., 2014; Ownsworth & Clare, 2006). Finally, some studies have even found associations between executive functions and declarative memory, and independence at instrumental

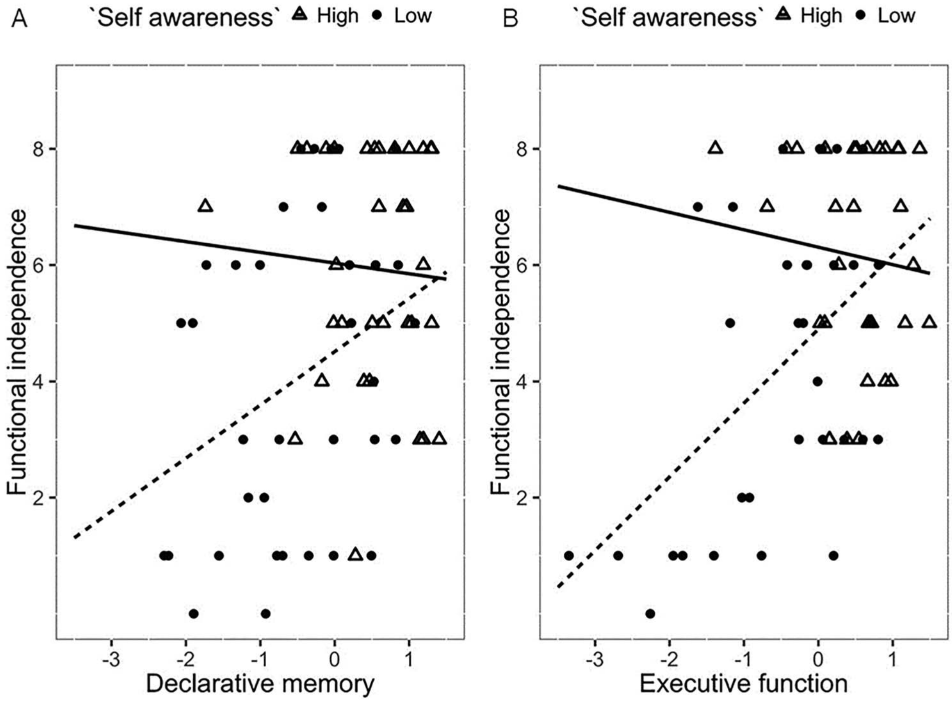

Fig. 1. Moderation effect of self-awareness (SA) in the relationship between (A) declarative memory and functional independence; and (B) executive function and functional independence. Solid and dashed lines correspond to high and low SA groups, respectively.

ADL (Overdorp et al., 2016; Perna et al., 2012). Considering these evidences, we particularly aimed to examine whether SA might work as moderator of the relationship between cognitive status and functional independence of the participants.

Results from the moderator analyses performed on these two factors revealed a differential contribution of SA in the relationship between either executive function or declarative memory, and functional outcome. First, a significant interaction between SA and executive function was found, so that deficits in executive function were associated with poorer functional outcome only in participants with low levels of SA. Conversely, in participants with higher levels of SA, this association was not present, suggesting that it may be moderated by and adjusted SA level in these participants. Indeed, it can be hypothesized that a right knowledge of the own deficits and their related limitations may increase motivation toward rehabilitations and thereby induce positive actions such as developing of compensatory strategies and searching for help and support when the environmental requirements are challenging. Altogether, these strategies result in more adaptive behaviors and higher independence in ADL (Ownsworth & Clare, 2006; Sasse et al., 2013). Further, higher awareness of the own executive limitations seems to be crucial to improve them, which, as it is well known (Perna et al., 2012; Spikman, Boelen, Lamberts, Brouwer, & Fasotti, 2010), in turn also influences the level of functional independence.

Contrary to executive functions, declarative memory did not show a significant interaction with SA, even though higher declarative memory scores were associated with better functional outcome. A thorough inspection of the scatterplots for the association between declarative memory and functional independence also suggests the existence of such association in the low SA group, at least at a descriptive level. Given the current sample size, it cannot be discarded that our analysis was not able to detect a subtle, but true effect of SA in this relationship. On the other hand, declarative memory might be considered as a prerequisite to reach an adjust level of SA. Indeed, the ability to maintain declarative information has been identified as a crucial component to achieve a functional level of SA. Participant's difficulties at learning and consolidating declarative information (as illustrated by lower scores at the HVLT) limit their ability to update and integrate knowledge about physical and functional consequences of ABI, and thereby their ability to achieve and maintain an adjusted representation of their deficits and capacities (Morris & Mograbi, 2013). Consequently, and even considering a potential subtle effect of SA to the relationship between declarative memory and functional outcome, such effect would be restricted.

These results have relevant clinical implications for those professionals working in the cognitive rehabilitations of patients with ABI. Based on them, patients with executive deficits and poor SA levels would benefit from the beginning by specific interventions thought to increase their level of SA. This would increase patient's functional independence through the use of a wider range of cognitive strategies, but would also result in higher motivation toward rehabilitation and better outcomes from it (Tate et al., 2014). In contrast, patients with declarative memory deficits and low SA would benefit more from directly intervening on their mnemonic difficulties, rather than aiming to increase their level of SA. According to our data, and considering declarative memory as a prerequisite for SA (Morris & Mograbi, 2013), rehabilitation-induced declarative memory enhancement would have a positive impact on SA that would be reflected in better functional independence (Giles et al., 2019; Kelley et al., 2014; Ownsworth & Clare, 2006; see also Villalobos et al., 2020a for a systematic review).

In addition, considering literature focused on neurorehabilitation, the previous results are non-exclusive with the idea that include metacognitive strategies during specific memory interventions could be beneficial to increase task performance and promote generalization to daily functioning (Cicerone et al., 2019). Cognitive rehabilitation in ABI patients must be performed using a comprehensive/holistic approach which although target specific cognitive impairments, also provide individual and group therapies that address SA of the impact of cognitive deficits, emotional, and psychological functioning through an organized and integrated therapeutic environment (Koehler, Wilhelm, & Shoulson, 2012).

Despite of the interesting relationship arose from the present analysis, this study is not exempt of limitations that should be carefully considered for a precise understanding of their implications. First, the SA measure considered here mostly regards to the metacognitive or intellectual dimension of SA. Emergent and anticipatory dimension of SA (Crosson et al., 1989), more related to the online awareness (Toglia & Kirk, 2000), could offer a more comprehensive view of the impact of SA in the relationship between cognitive status and functional independence. Second, participants included in the study had suffered moderate to severe ABI, so that the effect of mild ABI has not been considered. However, the functional outcome in the post-acute phase may vary much even under equivalent severities of brain injury in the acute phase (as illustrated, for instance, by GCS scores). Thus, we chose to select a homogeneous sample of participants in terms of functional status at the admission to the rehabilitation centre, including only persons who needed neuro-cognitive rehabilitation due to the consequences of their brain damage.

Finally, we restricted the present investigation to some cognitive functions (i.e., executive and declarative memory) and their assessments were limited to a few neuropsychological scores, which constrain the characterization of participants in those terms. Indeed, it can be hypothesized that declarative memory could be a general prerequisite to achieve and maintain adequate levels of SA which, in turn, may reduce not only the impact of executive dysfunction but also of other cognitive dysfunctions (e.g., visuo-spatial, attentional, etc.) on the final functional outcome. Accordingly, further studies, including a wider and more detailed range of cognitive functions are needed.

In conclusion, this study adds to the well-known association among cognitive performance, SA, and functional independence of patients with ABI. In particular, we showed that SA is able to moderate the relationship between executive functions and functional independence in ADL, but in case of declarative memory this moderation effect would be limited at best. Besides confirming the important role of SA in ABI patient's status, these results highlight the need to consider specific interventions on SA within the global rehabilitation process.

Supplementary material

Supplementary material is available at *Archives of Clinical Neuropsychology* online.

Funding

D.V. has been supported by a Ph.D fellowship from financed by the Camilo José Cela University.

Conflict of Interest

The authors declare no conflict of interest.

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