JIDR Journal of Intellectual Disability Research
Published on behalf of mencap and in association with IASSID

Journal of Intellectual Disability Research doi: 10.1111/jir.12266

VOLUME 60 PART 6 pp 523–536 JUNE 2016

Gestural praxis in young adults with mild to moderate intellectual disabilities

S. Pinto,[1] Y. Chong,[1] R. García,[2] A. Almeida,[1] M. V. Perea[2] & V. Ladera[2]

1 *Department of Social and Behavioural Sciences, ISMAI – University Institute of Maia, Portugal*
2 *School of Psychology, University of Salamanca, Spain*

Abstract

Background Praxis functioning in the population with intellectual disabilities (ID) has been poorly studied. The goal of this research was to look for a starting point to study the praxic functioning in young adults with mild to moderate ID.
Method Thirty young adults with ID and 30 young adults without ID, between the ages of 18 and 35 years, participated in this study. All participants completed tests that assessed gestural praxis.
Results It was possible to observe similar praxis behaviour in the group with ID in almost all domains studied, albeit showing statistical values lower than those of the group without ID.
Discussions Despite the high number of errors committed, the sample of participants with ID was able to reach the goal of praxic tasks performed; such errors may be associated with a deficit in the development of various brain functions and not only with praxis functioning, mainly related to a lower yield in terms of planning, monitoring and correcting intentional movement.

Keywords gestural praxis, intellectual disabilities, praxis functioning

Correspondence: Prof. Yamisel Chong Espino, Instituto Universitário da Maia, Av. Carlos Oliveira Campos, Castelo da Maia, 4475-690 Maia, Portugal (e-mail: yespino@docentes.ismai.pt).

Introduction

Cognitive models of praxic processing based on the models of language production systems have been proposed (Rothi *et al.* 1991, 1997; Cubelli *et al.* 2000a) which enable us to understand the complexity of the praxic system and its various components, and whose impairment could translate into apraxia.

According to the model presented by Rothi *et al.* (1991, 1997), there is an indirect or lexical pathway, which is responsible for the production and imitation of meaningful gestures, whilst its motor programming comes from the action semantic system that integrates the information elicited by the analysis of the stimulus (auditory, visual and visuo-gestural), which includes knowledge about the tools, their mechanical advantage and their relationship to action (Heilman *et al.* 1997).

There will still be access to the information stored in the lexicon of gestural representations of all gestures known by the individual which will allow the recognition of familiar gestures (action input lexicon), and the knowledge about the process for carrying out such known gestures (action output lexicon). The spatial-motor representation formulas of the learned movements or 'praxicons' once described by Liepman (1908) would be stored here.

Bartolo *et al.* (2003) proposed a modification to this model which includes the intervention of a work area, whose dysfunction could translate into a selective deficit in performing pantomimes, which were

observed by those authors in some patients. The pantomimes, although considered to be recognisable and meaningful gestures, are new and rarely experienced (Bartolo & Cubelli 2014), thereby implying the need for new motor programmes for their materialisation, as they would not be available in the long-term memory. The development of these programmes and their correct execution would involve the intervention of a creative mechanism to integrate and synthesise the perceptual inputs in conjunction with the information provided by the outputs of action-semantic and lexical systems. The working memory thus plays an important role corresponding to the workspace where the information is handled and transformed.

On the other hand, at the neuroanatomical level it is known that the mirror neuron system is activated by the observation and imagination of previously learned movements. The more skill or mastery of movement individuals have, the more activation we may find in this system (Reynolds *et al.* 2015). In this sense, one could speculate that some individuals may have a hypoactivated mirror neuron system so that it could translate into a poor execution of movements under verbal command or by imitation.

Whilst observing the praxis production one could incur in a variety of possible qualitative errors, which may be divided into four main categories: errors of content, space, time and other (Rothi & Heilman 1997).

As far as the production of movement is concerned, Glover (2004) proposed a model of planning/control which allows the predicting and explaining of action of body movements. The planning system operates before the motion is executed whilst is responsible for the selection and initiation of a motor programme. At the same time, the control system plays a role during the execution of the movement by monitoring the motor programme.

The analysis of the aforementioned models allows for a view of the complexity of praxis processing, which has been studied almost exclusively in patients with apraxia. However, defining criteria of apraxia assumes, among other things, the absence of an intellectual deficit justifying the inability to perform the movement (Liepman 1900), as individuals could have problems in terms of their understanding of the information transmitted. Yet there are studies on some domains of the praxic function in individuals with Down Syndrome, Autism and other pathologies. Thus, it would be interesting and feasible to study the praxic processing in individuals with mild to moderate ID, if one could control their level of understanding of the information transmitted.

The goal of this research is to look for a starting point to study the praxic functioning in young adults with mild to moderate ID, seeking to characterise them in terms of such functioning and understand whether there really is a deficit that could be construed as an apraxia.

To this end we intend to evaluate the performance praxis under verbal command and by imitation, the former being more prone to errors than the latter (Heilman & Rothi 1985), probably associated with a higher demand on motor planning (Bartolo *et al.* 2003), by performing different types of gestures. The pantomimes appear to be more difficult to perform than transitive gestures as they involve, among others, an attitude of abstraction (Goldstein 1948), as the reference literature has been showing changes in this domain in individuals with ID (Uhlmann *et al.* 2011).

An attempt will also be made to analyse the types of errors made in gestural praxic tasks, as a weak integration of spatio-temporal characteristics where the action by individuals with ID takes place, as previously observed by Guilman (1935).

Thus, we hypothesised that in young adults with mild to moderate ID (1) the performance in the gestural praxis functioning by imitation is greater than under verbal command; (2) more errors of space and time than content in the gestural praxis under verbal command and by imitation are made; and (3) the performance in the execution of pantomimes is worse than in the execution of the same transitive gestures, under verbal command and by imitation.

Method

Participants

Participants were selected from a non-profit organisation (NGO) which benefits from State support, in which occupational, recreational, therapeutic, vocational and residential support activities, among others, are developed. It is especially targeted toward individuals with ID or other difficulties that might compromise leading an active and independent life, from various districts of northern Portugal.

The sample consists of 30 participants, 18 males and 12 females with ages between 18 and 35 years (mean = 25.1, SD = 5.4), previously diagnosed with mild ID ($n = 19$) and moderate ID ($n = 11$) (following criteria by DSM-V, American Psychiatric Association 2013) and with a good level of understanding of information. Individuals with specific syndromes (Down Syndrome, Williams Syndrome, X-Fragile Syndrome) and/or with associated pathologies (epilepsy, autism) were not included. Their IQ was obtained via the application of the Wechsler Adult Intelligence Scale-III (WAIS-III) (Wechsler 2008) (mean = 52.9, SD = 15.6). Seven members of this sample were taking neuroleptic medication with the aim of controlling their behaviour disorders. Apart from this information, none of the 30 participants had a relevant clinical history or showed any physical limitations which hindered movement.

The group without ID comprised 30 participants (18 males and 12 females) living in the same geographical area of the ID sample, which met the predefined inclusion criteria: aged between 18 and 35 years (mean = 25.5, SD = 4.5), and with no known neurological, psychiatric and psychological problems (Table 1).

Materials

Sample selection

The WAIS-III was used to select the sample of individuals with intellectual disabilities in order to include only individuals with mild to moderate ID. The ranges of 50–55 to 70 (mild ID) and of 35–40 to 50–55 (moderate ID) in WAIS-III were considered.

A structured interview was held with the aim of collecting data and observing their level of understanding of information by applying a set of tasks which were adapted from Arias *et al.* (2006), seeking to determine whether participants were complying with the inclusion criteria.

Praxic skills assessment

Praxic skills assessment was done via the Florida Apraxia Battery-Revised Extended and Sydney (FABERS) (Power *et al.* 2010) and the Upper Limb Praxis of Gestural Assessment Battery to complement the assessment.

The FABERS, which was based in the cognitive model of praxis processing (Rothi *et al.* 1991, 1997), was intended to assess the functioning praxis at the level of the upper limbs. It evaluates the integrity of the action input lexicon and action semantic system through tool recognition and pantomime recognition/discrimination tasks. The integrity of tool/action associative knowledge was evaluated by tool selection usually applicable to the situation as well as by alternative selection tools. The above mentioned battery also evaluates the object/image recognition route, auditory processing route, lexical route and nonlexical route through the production of 20 pantomimes and 10 communicative gestures under verbal command and by imitation, with the pantomimes to be achieved by visual presentation of a photograph of the object. Finally, the semantic knowledge of action was evaluated from the application task of selecting pairs of animals based on taxonomy, habitat and visual attributes (Power *et al.* 2010). For the application of such a battery it was necessary to build all the required materials (cards and videos) based on data provided by the same authors.

Table 1 Socio-demographic characteristics of the sample

	Group		
	Without ID	**With ID**	***P***
Gender (male/female)	18/12	18/12	1
Age (μ,σ)	25.5 (4.5)	25.1 (5.4)	0.8
Level of education (μ,σ)	15.93 (2.35)	2.13 (1.78)	0.00*
Manual dominance (right/left/ambidextrous)	24/0/1	24/5/1	0.07

*$P \leq 0.01$.

Furthermore, it was necessary to develop an Upper Limb Praxis of Gestural Assessment Battery, based on the work done by other authors, to compare performing pantomimes with the execution of the same gestures with the actual use of the object, because the FABERS was not supposed to evaluate this latter type of gestures but whose comparison was needed to accomplish a goal we had set. This battery initially evaluated the individual's knowledge of objects and gestures by identifying 10 objects to be further simulated and/or used, as well as the selection of 25 gestures (five communicative, 10 pantomimes and 10 transitive) whose production was subsequently requested under verbal command and by imitation. We then proceeded with the elaboration of specific material (cards, real objects and videos) for the application of the items. See Appendix A.

Procedures

This research unfolded according to the principles set out in the Declaration of Helsinki. Both the research protocol and the informed consent were approved by the Ethics Committee of our Research Unit. The collection and processing of data were performed under the Data Protection Laws of Portugal (Law # 67/98 of 26 October).

The research project and its application were approved and monitored by the Director of the institution from which the group members with ID were selected. Participants in both groups were informed about their participation in the investigation and procedures to be performed. Informed consent was signed by all participants and, in the case of three individuals with ID, was only signed by their legal guardian. The signatures of the members of the group with ID were collected in the presence of the person responsible in the institution and approved by it.

Then we proceeded to apply the structured interview to the participants (of both groups), as a screening device with the aim of selecting and verifying that the inclusion criteria were respected. The WAIS-III was applied in order to include only individuals with mild to moderate ID. The tasks of verbal comprehension were only applied to those with ID, and their clinical data were subsequently checked after permission by the institution's proper authority in which this sample was selected. Afterwards, we proceeded to apply the tests in two different sessions to both groups: first, FABERS (about 60 min), then the Evaluation Battery Praxical Function Upper Extremity Gestural (about 30 min). Whilst the ID group was evaluated at the institution, the group without ID was evaluated elsewhere but following the same rules and conditions as the experimental group.

Statistical analysis

To compare the performance between the two groups under verbal command and by imitation the Mann–Whitney *U* test was applied, whilst the paired-samples *t*-test was used to compare the performance of each group in each of these conditions.

The two groups were compared with respect to three kinds of errors under consideration being analysed by using the Mann–Whitney *U* test, whilst applying the Wilcoxon Signed Rank Test to compare, within each group, the different types of errors under verbal command and by imitation. The errors were in turn compared with each other in each group using the Friedman Test. Finally, we applied the Mann–Whitney *U* test to compare the performance between the two groups whilst performing pantomimes and transitive gestures under verbal command and by imitation, whilst using the Wilcoxon Signed Rank Test to compare, in each group, their providing the two types of gestures, in the two conditions considered.

When the distribution was not normal we used non-parametric tests, namely Mann–Whitney *U* test to test for test differences between two independent groups, and the Wilcoxon Signed Rank Test and Friedman Test when the subjects of each group were measured under two or three different conditions/points in time, respectively. On the other hand, in the presence of scalar variables, whenever the distribution was normal, we used the independent-samples *t*-test (parametric-test) to compare the mean scores of the two different groups of participants.

Results

The performance in the gestural praxis under verbal command and by imitation

Differences were found ($p = 0.00$) in praxis gestural performance under verbal command between the group without ID (mean = 24.77, SD = 2.56) and the ID group (mean = 14.07, SD = 3.79) to be statistically

significant. We also observed statistically significant differences in praxis performance by imitation ($p = 0.00$) between both groups, with the group without ID showing a higher yield (mean = 21.80, SD = 3.27) than the ID group (mean = 11.57, SD = 3.17). Each group also showed statistically significant differences ($p = 0.00$) in their performance both under verbal command and by imitation, with both groups yielding a higher performance under verbal command than by imitation which does not corroborate the first research hypothesis; see Table 2.

The errors of content, time and space in the gestual praxis under verbal command and by imitation

The results showed statistically significant differences ($p = 0.00$) between the two groups with respect to the execution of the tree types of errors in analysis (content, time and space) during the execution of gestural praxis tasks, either under verbal command or by imitation.

Whilst the group with ID either under verbal command or by imitation showed fewer content errors (mean = 90.37, SD = 7.72; mean = 98.33, SD = 2.76), followed by time errors (mean = 87.57, SD = 10.34; mean = 92.47, SD = 5.69) and space errors (mean = 81.77, SD = 10.39; mean = 92.17, SD = 4.89) respectively, the group without ID under verbal command showed fewer time errors (mean = 99.90, SD = 0.55) than content errors (mean = 99.07, SD = 1.84) and space errors (mean = 98.23, SD = 1.36) and, by imitation, less content errors (mean = 100.00, SD = 0.00), followed by space errors (mean = 98.23, SD = 1.01) and more time errors (X = 98.07, SD = 1.14). See Table 3.

As far as the ID group whilst under verbal command is concerned, statistically significant differences ($p = 0.00$) were obtained among the three types of errors whilst compared to each other, whereas by imitation there were no statistically significant differences between the errors of time and space ($p = 0.08$).

The results however were in accordance with the second research hypothesis, as the group with ID yielded more space and time errors than of content under both conditions (verbal command and by imitation).

Execution of pantomimes and transitive gestures under verbal command and by imitation

Statistically significant differences ($p = 0.00$) were found between both groups insofar as the execution of pantomimes and transitive gestures are concerned, either under verbal command, or by imitation, with the group without ID yielding a superior performance in all assessed areas.

On the other hand there were statistically significant differences ($p = 0.00$), in the ID group, between performing pantomimes (mean = 4.10, SD = 1.75; mean = 1.97, SD = 1.52) and transitive gestures (mean = 8.80, SD = 0.71; mean = 3.70, SD = 1.60) under verbal command and by imitation, respectively. As far as performing transitive gestures is concerned both groups obtained better results (mean = 9.83, SD = 0.38; mean = 7.87, SD = 1.57) than in the execution of pantomimes (mean = 8.40, SD = 1.19; mean = 7.13, SD = 1.81), both under verbal command and by imitation. See Table 4.

Table 2 Analysis of praxic performance under verbal command and by imitation in each group and between groups

	Performance			
	Verbal command	**Imitation**	***t***	***P***
Group without ID	24.77 (2.56)	21.80 (3.27)	6.37	0.00*
Group with ID	14.07 (3.79)	11.57 (3.17)	5.27	0.00*
t	-12.81	-12.30		
P	0.00*	0.00*		

*$P \leq 0.01$.

Table 3 Comparative analysis of content, time and space errors under verbal command and by imitation between groups

	Group			
	Without ID	**With ID**	***U***	***P***
Under verbal command				
Content errors	99.07 (1.84)	90.37 (7.72)	32.50	0.00*
Time errors	99.90 (0.55)	87.57 (10.34)	31.00	0.00*
Space errors	98.23 (1.36)	81.77 (10.39)	12.00	0.00*
By imitation				
Content errors	100.00 (0.00)	98.33 (2.76)	270.00	0.00*
Time errors	98.07 (1.14)	92.47 (5.69)	55.00	0.00*
Space errors	98.23 (1.01)	92.17 (4.89)	23.50	0.00*

*$P \leq 0.01$.

Table 4 Comparative analysis of performance in the execution of pantomimes and transitive gestures under verbal command and by imitation in each group and between groups

	Group			
	With ID	**Without ID**	***U***	***P***
Under verbal command				
Pantomimes	8.40 (1.19)	4.10 (1.75)	27.00	0.00*
Transitive gestures	9.83 (0.38)	8.80 (0.71)	113.00	0.00*
Z	-3.72	-4.71		
P	0.00*	0.00*		
By imitation				
Pantomimes	7.13 (1.81)	1.97 (1.52)	14.00	0.00*
Transitive gestures	7.87 (1.57)	3.70 (1.60)	43.00	0.00*
Z	-1.92	-3.72		
P	0.01*	0.00*		

*$P \leq 0.01$.

Discussion

Some studies indicate that the performance of gestures under verbal command would be more problematic and therefore more susceptible to errors than by imitation. The imitation of gestures is not a simple process, because it involves the participation of working memory, requiring the transformation of perceived information into a motor programme (Bartolo *et al.* 2003) and may require a higher level of attention. The executive functioning also plays an important role as a facilitator of imitation by inhibiting imitative responses when undesirable (Van Leeuwen *et al.* 2009).

There are some references in the literature to changes in attention in individuals with ID (Bastert *et al.* 2012), with a significant lower performance as far as the executive function (Japundža-Milisavljevic & Macešic-Petrovic 2008; Alloway 2010; Danielsson *et al.* 2010; Bastert *et al.* 2012) and the working memory (both verbal and visuo-spatial) (Alloway 2010; Brankaer *et al.* 2013), when compared to other types of population. The involvement of all these components in the imitation process may explain the inferior performance of the ID group and the discrepancy of results when compared to the group without ID. On the other hand, with regard to

imitation and visuocognition, studies support the idea that individuals with ID can focus their gaze on a specific object or part and not notice the outstanding features that are being asked to imitate (Giuliani & Schenk 2015).

With regards to the second research hypothesis, the making by the ID group of a significantly greater number of space and time errors compared to the no-ID group, it may be related to the existence of changes in the planning systems and control movement which can lead to the making of an incorrect and/or inappropriate gesture in their characteristics. This is because, according to the model presented by Glover (2004), these systems are responsible for determining, among others, temporal and spatial parameters of motion as well as for monitoring the selected engine programme focusing on the spatial characteristics of the target. The poor integration of spatial–temporal data where the action takes place, as observed in individuals with ID (Guilman 1935). In addition, participants with ID could have difficulty accessing the movement formulas or 'praxicon' as suggested by Liepman (1908). However, it should be noted that it is possible to imitate unfamiliar gestures without accessing these representations, because there would be no memory thereof (Cubelli *et al.* 2000b).

The making of spatial errors can be associated with possible changes in terms of body image, the semantic knowledge of the body and/or access to this information, because the planning, initiation and effectiveness of any conscious body movement depend on the integrated knowledge that the person has of the parts of their body, still being the point of origin of all spatial relationships we have established with external objects (Fonseca 2007). Furthermore, the production and imitation of meaningful gestures require access to a semantic path (Rothi *et al.* 1991, 1997) which will access the body semantics (knowledge codes about body parts), significant predictor of performance in the execution of these gestures (Schwoebel *et al.* 2004).

The group without ID also presented body part as tool errors in particularly sensitive pantomimes to be produced as a symbolic gesture (e.g. Scissors), previously observed in healthy participants (Duffy & Duffy 1989). However, in our research, these errors were followed by corrective behaviour in the group without ID, but were absent in the ID group, which may be related to the presence of gaps or changes in the information process (Boot *et al.* 2012) and difficulties in terms of self-regulation of behaviour (Baker 1982), inhibition of behaviour and interference control (Bexkens *et al.* 2014), previously observed in patients with ID, which have been linked to human intelligence (Numminen *et al.* 2000; Colom *et al.* 2008; Yu *et al.* 2008).

Thus, whilst performing pantomimes, the ID participants made a large number of errors of the body-part-as-tool type as well as errors insofar as the relationship between body segment and object which may be associated with the presence of a viable semantic system to convey not only the correct information about the function and application of the tools, but also the understanding of the information transmitted (this was observed during the assessment of the participants); at the same time it showed failures in the final correct configuration of the hand in relation to the simulated object.

The making of a significantly higher number of temporal errors by the ID group can be related to the presence of automatisms and absence of error perception and correction, unlike that observed in no-ID group.

Moreover, the existence of a significantly higher number of content errors in the ID group, when compared to the group without ID could be explained by the fact that such errors were essentially made during the execution of communicative gestures, and can be related with gestures previously learned and used in their daily lives.

Regarding the third research hypothesis, the presence of a superior performance in the execution of transitive gestures (under verbal order and by imitation) in both groups can be explained by the fact that the making of these gestures be easier, requiring less participation of the working memory or imagination, because the use of the real object is guided by its structure and physical limitations, as well as the sensory information that is received in the hand–tool interaction (Randerath *et al.* 2011). On the other hand, pantomime implementation requires a detailed cognitive analysis of the gesture, motor imagination (Mozaz *et al.* 2002) and higher involvement of the working memory, inasmuch as it requires the ability to maintain a representation of the target and of the tool in the hand (Randerath *et al.* 2011).

In conclusion, it is our opinion that this study has contributed significantly to the understanding of some characteristics of the gestural praxis functioning in young adults with mild to moderate ID. Our ID group does not seem to show an apraxic behaviour because they are able to achieve the purpose or goal of almost all evaluated praxic tasks, despite the making of a high number of space and time errors. These may be related to a deficit in the development of various brain functions and not just the praxic function, with failures in the areas of integration, and especially with an inferior level of planning, control and correction of intentional movement, which could have influenced their praxis processing. Learning a new gesture can provide support to help improve communication in individuals with ID. Our results, contrary to other studies related to praxical function, but not in individuals with ID, indicate that we should consider a possible change in the direct path or direct path of imitation, often used in the process of teaching and learning in individuals with ID. We do not know if these features can be explained using an altered visual–spatial or visuocognición, or by hypoactivating mirror neuron system.

Strengths and limitations

The size of our sample can be regarded as too small to enable us to achieve a comprehensive understanding of all possible cases of ID; however, given the virtual nonexistence of published studies on this matter, we believe that this can be regarded as a preliminary study perhaps to open new doors for the study of even more specific cases. We also recommend that further research on the interface of praxis functioning and brain activity using neuroimaging techniques be carried out.

References

Alloway T. P. (2010) Working memory and executive function profiles of individuals with borderline intellectual functioning. *Journal of Intellectual Disability Research* **54**, 448–56. DOI: 10.1111/j.1365-2788.2010.01281.x.

Arias J., González M., Fernández V. & Bartolomé M. (2006) EVEM (Evaluación del Estado Mental) [Mental State Examination]. In: *Neuropsicología – Libro de Trabajo*, 3ed. *Neuropsychology – Workbook* (eds M. Bartolomé, V. Fernández & C. Ajamil), 3rd edn, pp. 465–7. Amarú Ediciones, Salamanca.

American Psychiatric Association (2013) *Diagnostic and Statistical Manual of Mental Disorders V (DSM-V)*, 5th edn. American Psychiatric Association, Washington, DC.

Baker L. (1982) An evaluation of the role of metacognitive deficits in learning disabilities. *Topics in Learning and Learning Disabilities* **2**, 27–35.

Bartolo A. & Cubelli R. (2014) The cognitive models of limb apraxia and the specific properties of meaningful gestures. *Cortex* **57**, 297–8. DOI: 10.1016/j.cortex.2014.01.007.

Bartolo A., Cubelli R., Della Sala S. & Drei S. (2003) Pantomimes are special gestures which rely on working memory. *Brain and Cognition* **53**, 483–94. DOI: 10.1016/S0278-2626(03)00209-4.

Bastert E., Schläfke D., Pein A., Kupke F. & Fegert J. (2012) Mentally challenged patients in a forensic hospital: a feasibility study concerning the executive functions of forensic patients with organic brain disorder, learning disability, or mental retardation. *International Journal of Law and Psychiatry* **35**, 207–12. DOI: 10.1016/j.ijlp.2012.02.010.

Bexkens A., Ruzzano L., Collot D'Escury-Koenings A. M., Van der Molen M. W. & Huizenga H. M. (2014) Inhibition deficits in individuals with intellectual disability: a meta-regression analysis. *Journal of Intellectual Disability Research* **58**, 3–16. DOI: 10.1111/jir.12068.

Boot F. H., Pel J. J., Evenhuis H. M. & Van der Steen J. (2012) Factors related to impaired visual orienting behavior in children with intellectual disabilities. *Research in Developmental Disabilities* **33**, 1670–6. DOI: 10.1016/j.ridd.2012.04.007.

Brankaer C., Ghesquière P. & Smedt B. D. (2013) The development of numerical magnitude processing and its association with working memory in children with mild intellectual disabilities. *Research in Developmental Disabilities* **34**, 3361–71. DOI: 10.1016/j.ridd.2013.07.001.

Colom R., Abad F. J., Quiroga A., Shih P. C. & Fores-Mendoza C. (2008) Working memory and intelligence are highly related constructs, but why? *Intelligence* **36**, 584–606. DOI: 10.1016/j.intell.2008.01.002.

Cubelli R., Marchetti C., Boscolo G. & Della S. S. (2000a) Cognition in action: testing a model of limb apraxia. *Brain and Cognition* **44**, 144–65. DOI: 10.1006/brcg.2000.1226.

Cubelli R., Boscolo G. & Della Sara S. (2000b) Cognition in action: testing a model of limbic apraxia. *Brain* **44**, 144–65.

Danielsson H., Henry L., Rönnberg J. & Nilsson L. G. (2010) Executive functions in individuals with intellectual disability. *Research in Developmental Disabilities* **31**, 1299–304. DOI: 10.1016/j.ridd.2010.07.012.

Duffy R. J. & Duffy J. R. (1989) An investigation of body part as object (BPO): responses in normal and brain-damaged adults. *Brain and Cognition* **10**, 220–36.

Fonseca V. (2007) *Manual de Observação Psicomotora – Significação Psiconeurológica dos Factores Psicomotores, 2ª ed. Psychomotor Observation Manual – Neuropsychological Meaning of Psychomotor Factors*, 2 edn. Âncora Editora, Lisboa.

Giuliani F. & Schenk F. (2015) Vision, spatial cognition and intellectual disability. *Research in Developmental Disabilities* **37**, 202–8.

Glover S. (2004) Separate visual representations in the planning and control of action. *Behavioral and Brain Sciences* **27**, 3–78.

Goldstein K. (1948) *Language and Language Disturbances: Aphasic Symptom Complexes and Their Significance for Medicine and Theory of Language*. Grune & Stratton, New York.

Guilman E. (1935) *Fonctions Psycho-Motrices et Troubles du Comportement:Étude de Tests Psycho-Moteürs Pour Enfants d'agescolaire [Psycho-Motor Function and Behavioral Disorders: Study of Psycho-Motor Tests for School-Aged Children]*. Foyer central d'hygiéne, Paris.

Heilman K. M., Maher L. M., Greenwald M. L. & Rothi L. J. G. (1997) Conceptual apraxia from lateralized lesions. *Neurology* **49**, 457–64.

Heilman K. M. & Rothi L. J. G. (1985) Apraxia. In: *Clinical Neuropsychology* (eds K. M. Heilman & E. Valenstein), pp. 131–50. Oxford University Press, New York.

Japundža-Milisavljevic M. & Macešic-Petrovic D. (2008) Executive functions in children with intellectual disabilities. *The British Journal of Developmental Disabilities* **54**, 113–21.

Liepman H. (1900) Das krankheitsbild der apraxie (motorischen asymbolie) [The disease picture of apraxia (motor asymbolia)]. *Monatschr Psychiatr Neurol* **8**, 15–44.

Liepman H. (1908) *Drei Aufsatze aus dem Apraxie Gebiet [Three Towers from de Apraxia Area]*. Karger, Berlin.

Mozaz M., Rothi L. J., Anderson J. M., Crucian G. P. & Heilman K. M. (2002) Postural knowledge of transitive pantomimes and intransitive gestures. *Journal of International Neuropsychological Society* **8**, 958–62. DOI: 10.1017/S1355617702870114.

Numminen H., Service E., Ahonen T., Korhonen T., Tolvanen A., Patja K. et al. (2000) Working memory structure and intellectual disability. *Journal of Intellectual Disabilitiy Research* **44**, 579–90. DOI: 10.1046/j.1365-2788.2000.00279.x.

Power E., Code C., Croot K., Sheard C. & Gonzalez Rothi L. J. G. (2010) Florida Apraxia Battery-Extended and Revised Sydney (FABERS): design, description, and a healthy control sample. *Journal of Clinical and Experimental Neuropsychology* **32**, 1–18. DOI: 10.1080/13803390902791646.

Randerath J., Goldenberg G., Spijkers W., Li Y. & Hermsdörfer J. (2011) From pantomime to actual use: how affordances can facilitate actual tool-use. *Neuropsychologia* **49**, 2410–6. DOI: 10.1016/j.neuropsychologia.2011.04.017.

Reynolds J. E., Thornton A. L., Elliott C., Williams J., Lay B. S. & Licari M. K. (2015) A systematic review of mirror neuron system function in developmental coordination disorder: imitation, motor imagery, and neuroimaging evidence. *Research in Developmental Disabilities* **47**, 234–83.

Rothi L. J. G. & Heilman K. M. (1997) *Apraxia: The Neuropsychological of Action*. Psychology Press, Hove, UK.

Rothi L. J. G., Ochipa C. & Heilman K. M. (1991) A cognitive neuropsychological model of limb praxis. *Cognitive Neuropsychological* **8**, 443–58.

Rothi L. J. G., Ochipa C. & Heilman K. M. (1997) A cognitive neuropsychological model of limb praxis and apraxia. In: *Apraxia: The Neuropsychological of Action* (eds L. J. G. Rothi & K. M. Heilman), pp. 29–49. Psychology Press, Hove, UK.

Schwoebel J., Buxbaum L. J. & Coslett H. B. (2004) Representations of the human body in the production and imitation of complex movements. *Cognitive Neuropsychology* **21**, 285–98. DOI: 10.1080/02643290342000348.

Uhlmann C., Widmann B. & Baier H. (2011) Erfassung kognitiver Defizite bei Patient mit Intelligenzminderung und Epilepsie [Detecting cognitive impairment in patients with mental retardation and epilepsy]. *Aktuelle Neurologie* **38**, 12–8. DOI: 10.1055/s-0030-1266064.

Van Leeuwen M. L., Van Baaren R. B., Martin D., Dijksterhuis A. & Bekkering H. (2009) Executive functioning and imitation: increasing working memory load facilitates behavioural imitation. *Neuropsychologia* **47**, 3265–70. DOI: 10.1016/j.neuropsychologia.2009.06.005.

Wechsler D. (2008) *Escala de Inteligência de Wechsler para Adultos, 3ª ed.Wechsler Adult Intelligence Scale*, 3rd edn. CEGOC-TEA, Lisboa.

Yu C., Li J., Liu Y., Qin W., Li Y., Shu N. et al. (2008) White matter tract integrity and intelligence in patients with mental retardation and healthy adults. *NeuroImage* **40**, 1533–41. DOI: 10.1016/j.neuroimage.2008.01.063.

Accepted 28 January 2016

Appendix A

Items and corresponding scoring of tasks of the Upper Limbs Gestural Praxic Function Assessment Battery

Naming objects

Instruction: 'Tell me the name of each of these objects' (present each object to be used later, one at a time)

	Score (0/1)
Toothbrush	
Comb	
Glass	
Mobile	
Chapped lipstick	
Pen	
Scissors	
Spoon	
Hammer	
Key	
Total (maximum 10 points)	

Identifying gestures

Instruction: 'Tell me what I'm to do.'

		Score (0/1)
Expressive intransitive	1. Saying goodbye	
	2. Sending a kiss	
	3. Calling (come here)	
	4. Ok	
	5. Silence	
Reflexive pantomimes	6. Brushing your teeth	
	7. Combing up	
	8. Drinking a glass of water	
	9. Answering your phone	
	10. Putting chapped lipstick	
Non reflexive pantomimes	11. Writing with a pen	
	12. Cutting a paper with scissors	
	13. Stirring the coffee with a spoon	
	14. Using a hammer	
	15. Unlocking a door with a key	
Reflexive transitive	16. Brushing your teeth	
	17. Combing up	
	18. Drinking a glass of water	
	19. Answering your phone	
	20. Putting chapped lipstick	
Non reflexive transitive	21. Writing with a pen	
	22. Cutting a paper with scissors	

(Continues)

(Continued)

			Score (0/1)
		23. Stirring the coffee with a spoon 24. Using a hammer 25. Unlocking a door with a key	
Total (maximum 25 points)			

Gesture selection

Instruction: 'I will perform three gestures. Tell me which one is right for the requested action.'

			Score (0/1)
Expressive intransitive	Send away	**1. Saying goodbye**	Ok
	2. Sending a kiss	Silence	Militar salute
	Saying goodbye	Ok	**3. Calling (come here)**
	Silence	**4. Ok**	Calling (come here)
	5. Silence	Ok	Saying goodbye
Reflexive pantomimes	Drinking a glass of water	Brushing your teeth	**6. Combing up**
	7. Brushing your teeth	Answering your phone	Combing up
	Putting chapped lipstick	**8. Drinking a glass of water**	Combing up
	Drinking a glass of water	Brushing your teeth	**9. Answer your phone**
	10. Put lipstick chapped	Drink a glass of water	Brushing your teeth
Non reflexive pantomimes	Stirring the coffee with a spoon	Using a hammer	**11. Writing with a pen**
	12. Cutting a paper with scissors	Writing with a pen	Using a hammer
	Unlocking the door with a key	13. **Stirring the coffee with a spoon**	Using a hammer
	Writing with a pen	Cutting a paper with scissors	**14. Using a hammer**
	15. **Unlocking a door with a key**	Stirring the coffee with a spoon	Writing with a pen
Reflexive transitive	Drinking a glass of water	Brushing your teeth	**16. Combing up**
	17. Brushing your teeth	Answering your phone	Combing up
	Putting chapped lipstick	**18. Drinking a glass of water**	Combing up
	Drinking a glass of water	Brushing your teeth	**19. Answering your phone**
	20. Putting chapped lipstick	Drinking a glass of water	Brushing your teeth
Non reflexive transitive	Stirring the coffee with a spoon	Using a hammer	**21. Writing with a pen**
	22. Cutting a paper with scissors	Writing with a pen	Using a hammer
	Unlocking a door with a key	**23. Stirring the coffee with a spoon**	Using a hammer
	Writing with a pen	Cutting a paper with scissors	**24. Using a hammer**
	25. **Unlocking a door with a key**	Stirring the coffee with a spoon	Writing with a pen
Total (maximum 25 points)			

Gesture production – under verbal order

Instruction: 'Show me how (…)'

		Score (0/1)
Expressive intransitive	1. Saying goodbye	
	2. Sending a kiss	
	3. Calling (come here)	
	4. Ok	
	5. Silence	
Reflexive pantomimes	6. Brushing your teeth	
	7. Combing up	
	8. Drinking a glass of water	
	9. Answering your phone	
	10. Putting chapped lipstick	
Non reflexive pantomimes	11. Writing with a pen	
	12. Cutting a paper with scissors	
	13. Stirring the coffee with a spoon	
	14. Using a hammer	
	15. Unlocking the door with a key	
Reflexive transitive	16. Brushing your teeth	
	17. Combing up	
	18. Drinking a glass of water	
	19. Answering your phone	
	20. Putting chapped lipstick	
Non reflexive transitive	21. Writing with a pen	
	22. Cutting a paper with scissors	
	23. Stirring the coffee with a spoon	
	24. Using a hammer	
	25. Unlocking a door with a key	
Total (maximum 25 points)		

Imitation of gestures

Instruction: 'Copy exactly the action that I do. Wait until I finish'

		Score (0/1)
Expressive intransitive	1. Saying goodbye	
	2. Sending a kiss	
	3. Calling (come here)	
	4. Ok	
	5. Silence	
Reflexive pantomimes	6. Brushing your teeth	
	7. Combing up	
	8. Drinking a glass of water	
	9. Answering your phone	
	10. Putting chapped lipstick	
Non reflexive pantomimes	11. Writing with a pen	
	12. Cutting a paper with scissors	

(Continues)

(Continued)

		Score (0/1)
Reflexive transitive	13. Stirring the coffee with a spoon 14. Using a hammer 15. Unlocking the door with a key 16. Brushing your teeth 17. Combing up 18. Drinking a glass of water 19. Answering your phone	
Non reflexive transitive	20. Putting chapped lipstick 21. Writing with a pen 22. Cutting a paper with scissors 23. Stirring the coffee with a spoon 24. Using a hammer 25. Unlocking a door with a key	
Total (maximum 25 points)		

Qualitative characterisation record of praxic tasks

Praxic Task: _____

Score			0	1	2	Total
Content	Perseveration		Total perseveration of gesture/previous motion	Perseveration of a portion of gesture/ previous movement	Does not persevere	
	Related Content		Unrelated content	Moderate relationship (somewhat related)	Correct content	
Temporal	Sequence	Adding an element	>1 element	1 element	Does not add	
		Omission of an element	>1 element	1 element	Does not omit	
		Transposition of an element	>1 element	1 element	Unchanged	
	Duration	Increase	>10 s	From 6 to 10 s	Execution within the expected time (±5 s)	
		Decrease	>2 s	2 s	Execution within the expected time (±5 s)	
	Occurrence (perseveration)		Over 4 repetitions	Execution of 3 or 4 repetitions	Realisation of 1 or 2 repetitions	
Spacial	Amplitude	Amplification	Wrong	Slight amplification	Correct execution	
		Reduction	Wrong	Slight reduction	Correct execution	
	Body part as a tool		Using part of your body	Automatic correction	Without replacement	
	Internal configuration		Does not recognise the body	Slight distortion in body configuration with the object	Good body configuration with the object	

(Continues)

(Continued)

Score		0	1	2	Total
		configuration with the object			
	External configuration	Misconfiguration of the object	Slight distortion in the object configuration	Good object configuration	
	Motion	Does not perform the characteristic and necessary movement	Moderate movement change	Correct movement	
Other	Unrecognisable response	Not recognised	Response with slight distortions	Perfectly recognisable response	
	No reply	Do not answer	Responds with moderate changes	Good answer	
Final score					