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Point-Light Display: A new tool to improve verb recovery in patients with aphasia? A pilot study

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Data availability statement: The data that support the findings of this study will be openly available in OSF at <https://osf.io/vznwb/>

Ethical statement

The study was approved by a local ethics committee (N° 2020-11-01). Before the experiment, all patients signed written informed consent forms. The experiment was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki.

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No conflict of interest

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Abstract

Some studies have demonstrated that Action Observation (AO) could help patients with aphasia to recover use of verbs. However, the role of kinematics in this effect has remained unknown. The main aim was to assess the effectiveness of a complementary intervention based on the observation of action kinematics in patients with aphasia. Seven aphasic patients (3 males, 4 females) aged between 55 and 88 years participated in the studies. All patients received a classical intervention and an additional, specific intervention based on action observation. This consisted in visualizing a static image or a point-light sequence representing a human action and in trying to name the verb representing the action. In each session, 57 actions were visualized: 19 represented by a static drawing, 19 by a non-focalized point-light sequence i.e., a point-light display with all dots in white, and 19 by a focalized point-light sequence i.e., a point-light display (PLD) with the dots corresponding to the main limbs in yellow. Before (pre-test) and after (post-test) the intervention, each patient performed the same denomination task, in which all actions were presented in photographs. The results showed a significant improvement in performance between pre and post-test, but only when the actions were presented in focalized and non-focalized point-light sequences during the intervention. The presentation of action kinematics seems crucial in the recovery of verbs in patients with aphasia. This should be considered by speech therapists in their interventions.

KEYWORDS: action verbs, aphasia, rehabilitation, action observation, point-light sequences, kinematics.

Introduction

Aphasia is a neurological disorder characterized by difficulty to communicate resulting from a progressive neurodegenerative process of the brain such as stroke or head trauma (Benson & Ardila, 1996). It can affect all oral language processing components (in production and comprehension) and is variably severe. The two main forms of aphasia are fluent and non-fluent aphasia. Non-fluent aphasia is characterized by drastically reduced language production with short sentences, and few words. Fluent aphasia is defined by conservation of the fluency of language with major qualitative reduction using neologisms or jargon (Goodglass, 1993). Regardless of type of aphasia, word-finding difficulties are virtually ubiquitous in aphasia. Several therapies based on language (e.g., Brady et al., 2016), or an association between language and pictures (e.g., Reymond et al., 2022) or between language and gesture (e.g., Hanlon et al., 1990; Rose et al., 2002) are usually proposed by speech therapists to rehabilitate language and to propose alternative communication devices in patients with aphasia. More recently, new types of therapy using action observation have been introduced (e.g., Marangolo et al., 2010). The principle of these therapies is that the same neuronal circuits, i.e., the mirror neuron system, support both language and action observation (Aziz-Zadeh et al., 2006; W. Chen & Yuan, 2008; Tettamanti et al., 2005). Action and language are viewed as conceptually related (Barsalou, 1999; Bidet-Ildei et al., 2020; Bidet-Ildei & Toussaint, 2015; Chen & Yuan, 2008; Gallese, 2005). Experimental studies have shown that action observation is an effective means of retrieving words in patients with aphasia (Bonifazi et al., 2013; Chen et al., 2019; Marangolo et al., 2010, 2012). This effect could be related to the strength of activation in the mirror neuron system (Chen et al., 2019; Marangolo et al., 2012) and may be more efficient when action observation corresponds to the motor repertoire of patients. Accordingly, Marangolo et al. (2012) showed that only movements belonging to the motor repertoire of individuals are efficient to retrieve language in patients with aphasia, whereas animal and

mechanical movements not. In the same manner, Chen et al. (2019) showed that the activation of mirror neuron system was stronger when patients visualized hand actions compared to dynamic-object and that this was associated with improved vocabulary extraction and spontaneous speech. Their results suggest that the efficacy of action observation therapy in language retrieval could be directly related to the activation of the mirror neuron system. However, it is still unclear how this treatment approach works. In typical adults, a number of studies have shown that action observation is linked to action verb processing (see Bidet-Ildei et al., 2020 for review). For example, it has been shown that the observation of human actions facilitates action verb processing (e.g., Beauprez & Bidet-Ildei, 2017) and action-verb memory (Villatte et al., 2022). Interestingly, the link between action and language could be influenced by the kinematics i.e., the motion of each limb of the body (Beauprez & Bidet-Ildei, 2018; Villatte et al., 2022) and the somatotopy of action i.e., the correspondence between one part of the body and one part of the motor cerebral cortex (Beauprez & Bidet-Ildei, 2018; Bidet-Ildei et al., 2017). For example, in healthy individuals, the facilitation of action verb processing disappears when action is presented with non-biological kinematics, suggesting the importance of kinematics in the link between action observation and action verb processing. Moreover, only perturbation of the main limbs of action has an effect on the link between action and language, which suggests that to be efficient, the link between action and language should respect the biological kinematics of action and somatotopy.

In this context, the aim of the present study was to assess the role of kinematics and somatotopy on verb retrieval in patients with aphasia. For this reason, we proposed to use a point-light display (PLD) paradigm approach (Johansson, 1973). PLDs are animated sequences of dots representing the joints of an actor performing an action. This type of paradigm is adapted for our objective insofar as the action is perceived only from the kinematics of the actor. Moreover, PLD can be easily modified to more or less determine a part of action (Decatoire et al., 2018).

Therefore we propose here the PLD technique for several reasons: 1) motion capture enables to obtain the kinematics of real action, 2) it permits to suppress all context 3) it potentially recruits higher-order cognitive processes (e.g., Martins et al., 2017). As a result, we suggest that PLD is perfectly adapted to investigate the strict mechanisms related to kinematics for language improvement. Moreover, we hypothesise that without context (real scene) and without ambiguity (pantomime), PLD could contribute to the generalization of action semantics (Kiran & Thompson, 2019). To evaluate the potential role of kinematics in the effectiveness of action observation in patients with aphasia, we propose to compare how the observation of PLD actions can improve word retrieval in comparison to the observation of actions represented in static images. To assess the role of somatotopy, we contrasted two conditions of PLD: non-focalized where all dots were white, and focalized PLD, where the dots representing the main joints in the action were in yellow. We hypothesize that action observation in PLD should be more effective than action observation in static images and that focalized PLD should be more effective than non-focalized PLD to retrieve action verbs in patients with aphasia. Actually, if action observation activates a resonance in the brain respecting the somatotopy organization of cortex, we suggest that focalization of the limbs preferentially implied in the motion could be related to the strength of activation of the associated motor representation.

Method

Participants

All French-speaking volunteers over 18 years of age with aphasia could be included in the study. Inclusion criteria were: a single cerebrovascular accident or a brain trauma at least one month prior to the investigation with no previous neurological, psychiatric, or substance abuse history. Exclusion criteria were: untreated visual problems or attentional difficulties. Finally,

7 patients (3 males, 4 females) aged between 55 and 88 years were included in the study. All patients were classified as aphasic by a medical team composed of neurologist, practitioners, and speech therapists. All patients presented word-finding difficulties assessed with a denomination task. They had no articulatory deficits with preserved word repetition and no difficulties of comprehension assessed by the capacities to match two semantically related pictures. The study was approved by a local ethics committee (The “CER Tours-Poitiers committee”, N° 2020-11-01). Before the experiment, all patients had signed written informed consent forms. The experiment was performed in accordance with the ethical standards of the 1964 Declaration of Helsinki.

Material

The PLDs were chosen in the free accessible PLAViMoP platform (see <https://plavimop.prd.fr/en/motions> and Bidet-Ildei et al., 2022). Fifty-seven PLDs representing everyday life actions with a recognition rate superior to 60% were chosen: 31 representing actions produced with all the body (i.e., global motor skills such as running, walking, jumping), 17 representing action produced with only the top of the body (i.e., fine motor skills such as writing , drawing, drinking), 6 represented interactions between two individuals (i.e., handshake, High-five, kiss) and two represented emotions with just the face visible (i.e., anger and joy to be used respectively as “Scream” and “Laugh” actions). The complete list is available in Appendix 1. After the PLDs were chosen, each sequence was modified using PLAViMoP software (Decatoire et al., 2018) to obtain two versions. In the non-focalized sequence, all the dots were presented in white on a black background. In the focalized sequence, the dots representing the main limbs were presented in yellow while the others were presented in white. All other characteristics such as size of the dots or point of view stayed identical between the two conditions.

Concerning the drawing images, they were directly extracted from the French database Clic-Image 2.0: <https://www.reseau-canope.fr/canope-academie-dijon/Presentation-de-Clic-images-2-0.html> or were built with the same drawing style when they did not exist.

Finally, concerning the photographs, they were extracted on free database on google images or corresponded to captures made in our lab.

The level of recognition of PLD was extracted from the PLAViMoP database in January 2021. The recognition of drawing and photographs were tested with two pilot studies made on line in 18 and 21 neurotypical adults. The results are in Appendix 1. All material is available in OSF at <https://osf.io/vznwb/>.

Procedure

The experimentation was performed in three steps (see Figure 1). After patient inclusion, he/she took a pre-test consisting of a denomination task of 57 actions from photographs. The speech therapist wrote the patient response but did not give the correct answer when the response was false or absent. Afterwards, the patient followed a 2-week period of classical rehabilitation associated with an intervention made by speech therapists. The classical rehabilitation was identical for all participants and consisted in different exercises usually employed in patients with language production difficulties (e.g., motor mobility of face and tongue, repetition of words, denomination of images, etc.). The additional intervention consisted in sessions of action denomination associated with action observation proposed in three blocks corresponding to three types of support (19 drawing, 19 non-focalized PLD and 19 focalized PLD). If the patient failed to produce the verb associated with the observed action, the speech therapist could help him/her to find the right word (for example by giving the first part of the word). In all cases, the correct verb was given after each trial. Each session lasted about 20 minutes and was repeated 5 days a week for two weeks. Patients always saw the same actions with the same

support during all the sessions, but both the order of blocks and the order of verbs were randomized between sessions. Moreover, to present each verb with each support, three different patient files were created (see Figure 1). Thus, all verbs were used in either the picture conditions or the PLD condition, with no possibility of an individual being influenced by the prior stimuli condition. Moreover, thanks to the three different patient files, each action had been presented with each support (drawing, focalized PLD and non-focalized PLD), which neutralised the possible effect of a priori recognition differences between the different actions used. Before the first session, all patients were familiarized with PLD and drawing presentations of actions with examples that did not appear in the main experiment.

After the intervention, each patient took a post-test consisting in the same action denomination task with the photography they had produced in pre-test, but in a different order. Correct, “false” or “absent” performance was assessed by the speech therapist.

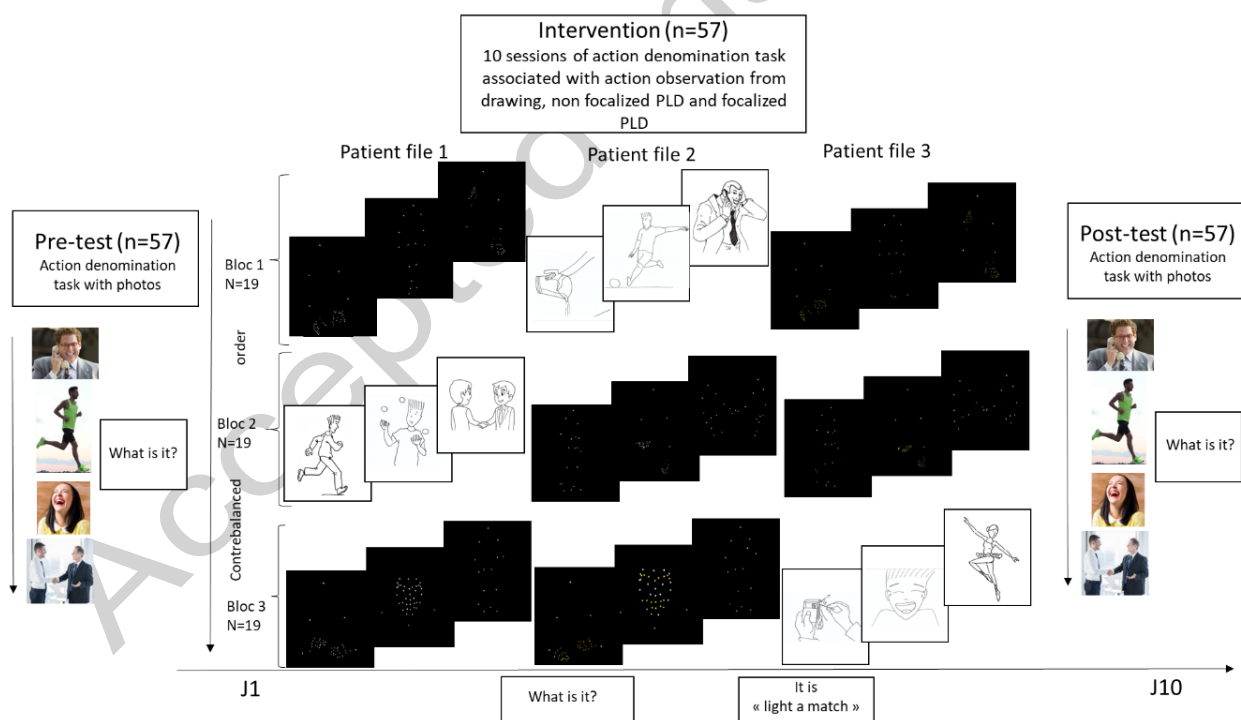


Figure 1: Study procedure. Each participant made three phases in 10 days: a pre-test consisting in judging 57 photographs (J1), an intervention phase where he/she was trained with 19 pictures, 19 non-focalized PLDs and 19 focalized PLDs and a post-test identical to the pre-test (J10).

During each session of the intervention, patients performed three blocks of denomination tasks based on the drawings, non-focalized PLDs and focalized PLDs presented in counterbalanced order between sessions. For one patient the same actions were presented with the same support during the 10 intervention sessions.

Data analysis

Action denomination task performance was assessed in pre and post-test for each patient by the experimenter, who was blinded concerning how the action had been performed during intervention. The analysis was performed with the JASP free software version 16.2. As the data did not violate the sphericity assumption assessed by a Mauchly test (all $p > .08$), repeated ANOVA was made with the support of action observation during the intervention (drawing, non-focalized PLD, focalized PLD) and the moment of the study (pre-test, post-test) as factors. Following our hypothesis, the contrasts between the performance in post-test and the performance in pre-test were calculated for each support with unilateral student t-test. Bonferroni's corrections were applied for multiple comparisons (Armstrong, 2014). Finally, we made an ANOVA on the mean correct recognition rate of each action during the 10 intervention sessions by considering the type of support as repeated factor. For all analyses, $p < 0.05$ was considered as significant. Eta squared (η^2) indicates the effect size.

Results

Table 1 shows the demographic and clinical characteristics of the seven study participants (4 males, 3 females). The mean participant age was 68 years (SD=13 years) and the mean educational level was 11 years (SD=2 years). All aphasic patients had had a left ischemic stroke with the exception of one patient (patient 1), who was a head trauma victim. Three patients had fluent aphasia and four patients had non-fluent aphasia (patients 2, 3, 4, 6).

Table 1: Sociodemographic and Clinical patient data. The intervention number corresponded to the patient file (see material and procedure).

Patient Number	Sex	Age	Number of years of education	Type of aphasia	Type of injury	Time post-onset	Results in denomination task (pre-test)
1	F	59	12	Fluent	Brain trauma	4 months	29/57
2	F	55	14	Non-fluent	Left hemorrhagic stroke	20 years	36/57
3	F	88	9	Non-fluent	Left ischemic stroke	1 year 8 months	15/57
4	M	78	12	Non-Fluent	Left ischemic stroke	1 month	18/57
5	M	57	12	Fluent	Right ishemic stroke	3 months	29/57
6	F	60	9	Non-fluent	Left ischemic stroke	4 years et 3 months	18/57
7	M	79	9	Fluent	Left ischemic stroke	3 months	28/57

The analysis showed a significant effect of the moment of the study ($F(1,6)=6.76$; $p=.04$, $\eta^2=0.35$) with better scores of recognition after intervention (Mean=62.15%, SD=12.49) than before intervention (Mean=43.36%, SD=12.56). No effect appeared between the supports used during the intervention ($F(2,12)=0.02$; $p=.98$) with a marginal mean equal to about 52% of recognition for all supports. Interestingly, we observed an interaction between the moment of the study and the support used during the intervention ($F(2,12) = 4.81$; $p =.03$, $\eta^2=0.05$) indicating that PLDs were more beneficial than drawing (Figure 2). Moreover, contrast analysis showed that the difference between pre and post-test was significant, with focalized PLD ($t_6=2.80$; $p=.04$, $\eta^2=0.22$) and non-focalized PLD ($t_6=3.54$; $p=.01$, $\eta^2=0.31$) with mean improvement of respectively 21 and 26 % of improvement. No significant difference between pre and post was found with drawing (9% of improvement, $t_6=1.03$; $p=.35$).

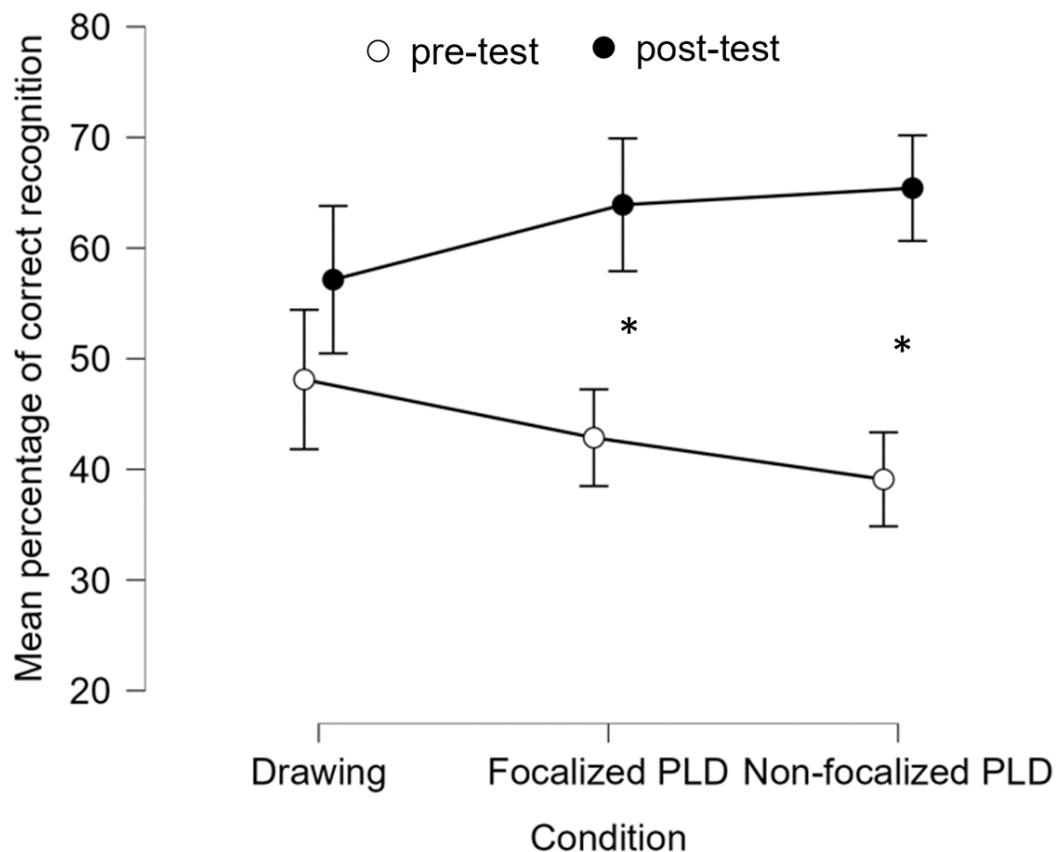


Figure 2: Mean percentage of correct recognition depending on the support used during the intervention and the moment. Error bars represent the standard error. * represents a significant difference at $p < .05$

Remarkably, these results cannot be due to differences in pre-test between the different supports of recognition ($F(2,12)=1.66$; $p=.23$). If we consider the mean recognition rate of each action during the 10 intervention sessions, we obtained no difference ($F(2, 112)=1.79$; $p=0.17$). For all supports the recognition approximated 50% of actions.

Discussion

Using the point-light display paradigm, this experiment aimed to confirm the potential interest of action observation therapy to rehabilitate word-finding difficulties in patients with aphasia and more specifically to demonstrate the importance of kinematics and attentional focalization in the effect.

Our findings confirm the potential benefit of action observation therapy in aphasia (see Marangolo & Caltagirone, 2014 for a review) by demonstrating an improvement of the denomination competencies after action observation therapy. This corroborates the idea that action observation and action verb processing are related through semantic resonance and activate similar action representations (see Bidet-Ildei et al., 2020 for a review). Therefore, action observation could activate the semantics of the action and consequently facilitate retrieval of the associated word. Interestingly, we show for the first time that kinematics is essential to significantly improve the performance of patients with aphasia. In fact, improved performance in patients with aphasia is significant only for point-light display conditions. Moreover, based on the effect size analysis, we observed moderate and large effects of improvement for PLD in focalized ($\eta^2=0.22$) and non-focalized ($\eta^2=0.31$) conditions, respectively. This confirms the importance of biological kinematics in action observation therapy in comparison with static stimuli (see Chen et al., 2015 for similar results) and suggests that point-light display could be a robust method for improving verb denomination in patients with aphasia. This effect was not explained by a better recognition of actions when they are presented in point-light display because if we consider the mean correct recognition during the intervention, we did not obtain any significant difference between drawing, focalized PLD and non-focalized PLD. This argues for the idea that the link between action observation and language is implicit (e.g., Beauprez & Bidet-Ildei, 2018) and suggests that the use of PLD could further activate the sensorimotor representations associated with action-verb. However, previous studies have shown that context is important in language processing in healthy adults (Beauprez et al., 2018; Beauprez et al., 2019, 2020) or patients with aphasia (Gili et al., 2017). For example, Gili et al (2017) showed in a population similar to ours (10 left ischemic stroke) that action observation enhances verb retrieval regardless of action presentation (in actual everyday life vs familiar pantomime context). However, recruitment of the sensory-motor

cortices during the observation of actions was limited to the presentation of action in actual everyday life context, suggesting that context could increase motor simulation processing. This discrepancy between these results and our findings could be related to the status of kinematics in humans. Numerous experiments have shown that 1) humans are very sensitive to biological kinematics (Bardi et al., 2011; Bidet-Ildei et al., 2014; Simion et al., 2008), 2) kinematics is essential in action recognition and interpretation (Bidet-Ildei et al., 2022; Johansson, 1973; Martel et al., 2011) and 3) kinematics is crucial to the link existing between action observation and action-language processing in healthy adults (Beauprez & Bidet-Ildei, 2018). Barsalou, 1999, indicated that to understand a word, we call upon sensory-motor perceptual engrams. For example, to understand and remember the word “apple”, we reactivate the sensory-motor traces of its shape, its color, its texture, its smell and its taste. More recently, in the Act-in model developed by Versace (2014), it is argued that the meaning of an element emerging from the activation (from past experiences) and integration (present experience) of multiple sensory-motor traces. We can therefore hypothesize that while kinematics is sufficient to activate the trace of an-action verb in memory, other sensory motor experiences, notably context, can strengthen activation. Testing this hypothesis could be a good point in future research, such as contrasting PLDs with natural video for semantic tree structure. Finally, the positive impact of kinematics could also be explained by the effect of “generalization” proposed by Kiran & Thompson (2019). In reality, a word can encompass several meanings and be associated with many different actions. For instance, while the verb “throw” can refer to sending something away, actually the associated action is different depending on the context (e.g., throw a ball, throw a javelin, throw a shot put). Therefore, representing the motion only by kinematics could potentially be associated with more motor experiences and consequently, could promote access to a more general definition of the verb. More explicitly, constraining the representation of the word “throw” to our example of the javelin throw could induce interference with these other

meanings through specificity, whereas treating and understanding the kinematics of the action of throwing would allow generalization of its meaning and thereby favour richer language ranging from the most cartesian definition to the most conceptual. According to this view, Thompson et al., (2013) argue that a verb with one argument (like "laugh") is simpler than one with three arguments (like "phone" (an agent who calls + the theme of calling + an agent who is called)). However, it is beneficial to work with verbs with three arguments, because they engage not only the work of the words but also their vocation, their syntax. In some way the PLD stimuli, by means of mirror neurons, makes the patient "replay" the action so that he can find its natural syntax.

Concerning focalization, no positive effect was retrieved in our study while in the literature, several experiments have shown that action-language has somatotopic representation (Beauprez & Bidet-Ildei, 2018; Boulenger et al., 2009; Hauk et al., 2004). Two major explanations can be considered. First, it is possible that changing the color of some limbs is not sufficient to induce focalization. Actually, humans perceive very quickly and accurately all the points presented in a point-light display (Johansson, 1973) and in our experiment, participants saw the entire motion in focalized as well as non-focalized conditions. Therefore, it is possible that our patients did not pay attention to the differences between the two conditions and apprehended the visual scene globally in both cases. This is all the more likely insofar as the contrast between the focalized and non-focalized points was not very high (yellow vs white points). Another hypothesis could be that the focalization was perceived but had no influence on our patients' word recovery. According to this view, Puglisi and collaborators (2018) showed that attentional focus during action observation could at once improve specific activation of the focused limbs and provoke concomitant inhibition of other limbs. Therefore, we can hypothesize that the absence of positive impact provoked by the focalisation on the

main limbs of action could be explained by a negative impact on the non-focalized limbs. This should be investigated in future work.

Limitations and future research

This study is not without limitations. First, our sample size was small and relatively heterogeneous. Actually, even though our sample size was determined by the number of patients generally participating in this type of experiment (e.g., Marangolo et al., 2010, 2012), it stayed relatively modest. However, it should be borne in mind that this was a pilot study to confirm the feasibility of a randomised clinical trial. Moreover, we grouped together patients suffering from fluent and non-fluent aphasia. Therefore, it will be important to replicate the findings with more participants and to assess whether the benefit could be different in the two patient populations.

Second, the mechanism related to the efficiency of point-light display was not tested, and future research should more specifically determine the role of biological kinematics in the recovery of action-verbs.

The third limitation is the lack of follow-up to ensure that the achievements are maintained.

Finally, while some studies have shown that the link between action observation and action-verbs is carried out by some parts of action in healthy participants (e.g., Beauprez & Bidet-Iledei, 2018), we did not find any effect of the focalization of the main limbs involved in the action in our patients. Other work should assess the potential effect of focalization and try to determine why it does not seem essential to the recovery of verbs in patients with aphasia.

Conclusion

In conclusion, this study suggests that point-light display can support the effect of action observation in the recovery of action language. This confirms previous literature about the interest of action observation in patients with aphasia and suggests that kinematics could be

crucial. As a new free platform of point-light display is now available on line (PLAViMoP, (see PLAViMoP Bidet-Ildei et al., 2022, <https://plavimop.prd.fr/en/>), this opens new interesting perspectives in remediation by language-speech therapists for patients with aphasia.

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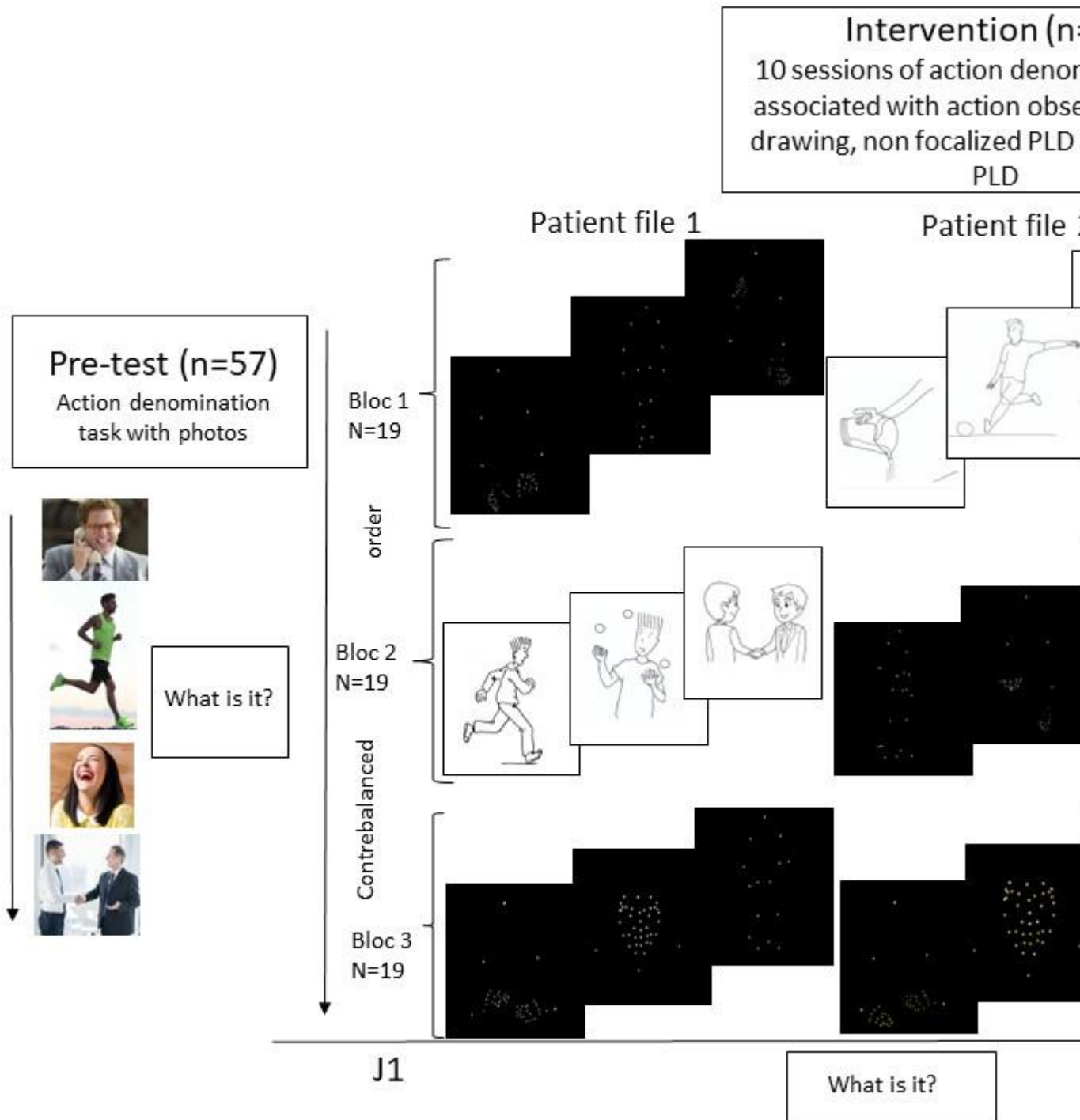
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Appendix 1: List of actions used and their percentage of recognition in each situation (PLD, drawing picture and photographs) by typical adults. For PLD recognition, the percentages were directly extract from the platform in January 2021. For drawing and photographs, the percentage of recognition has been calculated from two previous pilot studies made online in 18 and 21 neurotypical participants respectively. Importantly, as each action was shown with

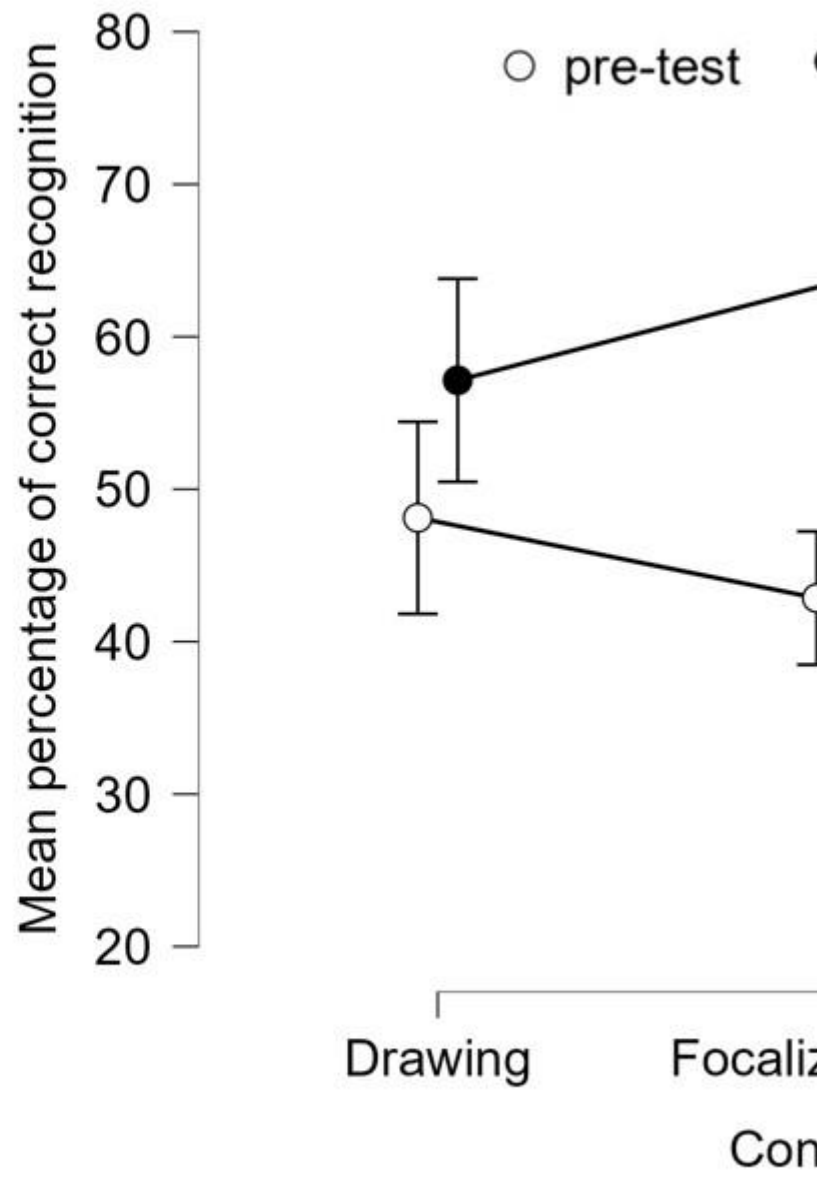
each type of support, the potential differences existing between the different actions cannot affect the results of the experiment.

Action	Type of movement	PLD recognition	Drawing recognition	Photographs recognition
Bounce a ball	Fine	65	94	80
Brush your teeth	Fine	64	94	100
Clean	Fine	86	94	100
Count	Fine	93	100	100
Cut	Fine	73	100	100
Draw	Fine	65	94	100
Drink	Fine	100	100	100
Eat	Fine	82	100	100
Juggle	Fine	92	94	100
Light a match	Fine	100	100	100
Open a pot	Fine	71	88	100
Phone	Fine	90	88	90
Point	Fine	96	100	100
Pour	Fine	82	88	95
Type	Fine	90	88	100
Write	Fine	88	100	100
Write an sms	Fine	67	77	100
Applaud	Global	95	94	100
Cross	Global	79	88	100
Crouch	Global	80	77	61
Cuddle	Global	78	83	66
Dance	Global	93	100	100
Fall	Global	95	94	95
Golf	Global	100	94	71
Hop	Global	91	44	42
Jump	Global	100	66	100
Kick	Global	81	100	85
Military salute	Global	67	72	90
Move back	Global	61	100	23
Pedal	Global	94	100	100
Pick up	Global	95	94	85
Put down (place the object on the floor)	Global	75	83	71
Pull	Global	69	94	100
Punch	Global	100	88	100
Push something	Global	65	94	100
Push up	Global	90	66	100
Run	Global	96	100	100
Salute (the bow)	Global	91	72	61

Say hello	Global	89	94	95
Scratch	Global	85	94	100
Shoot	Global	77	94	95
Sit down	Global	83	100	100
Stand up	Global	96	94	100
Step get off	Global	87	83	100
Step get on	Global	86	100	100
Sweep	Global	74	94	100
Throw a ball	Global	81	88	100
Turn	Global	91	94	57
Walk	Global	100	100	100
Carry somebody	Interaction	87	88	85
Cuddle	Interaction	75	88	90
Handshake	Interaction	77	88	95
High five	Interaction	82	77	80
Kiss	Interaction	61	94	100
Push somebody	Interaction	88	88	100
Laugh(Joy)	Emotion	78	94	100
Scream (Anger)	Emotion	70	100	100



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