Pointing and Action: Performance Effects on Remembering Geometrical Figures

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ABSTRACT
Depending on the task at hand, pointing has been shown to sometimes help, sometimes hinder, or to simply have no effect on learning and memory. In this study we directly compared the effects of pointing and action in two visuospatial memory tasks. Twenty-seven participants were asked to remember geometrical figures in three different conditions: 1) Visual Observation – e.g., looking at the figures, 2) Action – e.g., placing dots on the vertices of the figures, and 3) Pointing – e.g., pointing towards the vertices of the figures. Our results show that there is no significant difference in performance between pointing and action in recall and recognition of the geometrical figures nor did pointing for longer or shorter amounts of time affect performance. These results give direct evidence that pointing is not significantly different than action in this kind of visuospatial memory task. Our experiment did not directly involve language or problem solving but it did use stimuli that are not only coordinates but are also concrete forms. In this sense this study attempts to explore the boundaries between current research that has looked at pointing in the context of language and pointing independent of language. Although we predicted better performance for pointing in comparison to both visual observation and action we propose that the additional information that pointing may provide was not powerful enough to surpass and outperform the information acquired through visual observation and thus hindered performance.

1.1 Introduction
It has been well established that co-speech gesture forms a tight link with language prosodically, semantically, and pragmatically (Kendon, 2004; McNeill, 1992) and that it serves both the speaker and the interlocutor (Alibali & Kita, 2010; Hostetter, 2014; Ping & Goldin-Meadow, 2010; among others). Pointing is defined as a gesture that can be used with or without spoken language. It can stand alone because it embodies indexical and referential properties that allow it to be understood without the support of language (McNeill, 2012; Goldin-Meadow, Levine, Zinchenko, Yip, Hemani, Factor, 2012). The pointing gesture can be performed with an object, the index finger, the extended arm, hand and index finger, as well as with other parts of the body such as the mouth, the eyes, the foot, etc. Although pointing and other gestures are actions they differ from action in that gesture sits between concrete action and abstract language and often serves as a bridge between the two (Goldin-Meadow, 2010; Goldin-
Meadow, Beilock, 2012). Since gesture also shares properties of concrete action, such as physical movement, and abstract language, such as symbolic meaning, gesture’s interactions with, and boundaries between, action and language are not always clear and may be situation dependent (Goldin-Meadow, 2010).

1.2 Pointing in Early Childhood

The ability of pointing to combine indexicality and semantic relationships has been of interest to researchers because of its importance in early childhood cognitive and language development. Behne et al (2012) found that by the age of 12 months infants demonstrate the use of pointing as an intentional communicative tool (see also Gliga & Csibra, 2009). Özçalışkan and Goldin-Meadow (2005) found that infants’ use of gesture + speech combinations predicts when an infant will begin to produce speech + speech word combinations. Such findings provide evidence that gesture, and specifically pointing, can act as a bridge between uncoded action and language use and development.

However, for children and adults who have already acquired language proficiency and no longer use pointing as a language “bridge”, the role of pointing in cognition and memory seems to depend on situation or context and it is not clear whether pointing is beneficial. For example, young children who learned a conservation task, in this case a task asking children to discern if a quantity of liquid changes or doesn’t change (is conserved) when the size and/or shape of its container changes, profited from learning strategies that included the observation or production of representational or iconic gestures (that is, gestures which included some kind of transparent relationship with the actual target reference) but there was no evidence of profit when pointing was used instead (Goldin-Meadow, Beilock, 2012). Also, concrete and abstract gesture were found to help in math learning strategies (Novack, Congdon, Hemani-Lopez, & Goldin-Meadow, 2014) while pointing in a mental rotation task did not help (Levine, S. C., Goldin-Meadow, S., Ehrlich, S., & Tran, 2009).

1.3 Gesture vs. Action

Novack, et al (2014) looked at whether gesture is beneficial to learning because it is an action or because it is an action that represents abstract ideas. Children were taught three strategies for solving math-equivalence problems using action (e.g. physically moving numbers), concrete gesture (e.g. miming the movement of numbers without touch) or abstract gesture (e.g. using a two-fingered “v” point and a one-
fingered point) while speaking. Results showed that action was least effective in learning while miming was better and pointing was best especially when considering long term learning development. They proposed that abstract gesture (in this case, pointing) is more effective than action in learning because it abstracts away from action, although it is less abstract than language (See also Cook, Yip, and Goldin-Meadow, 2012).

Working with adults Beilock and Goldin-Meadow (2011), through an ingenious use of the Tower of Hanoi (TOH) problem solving task, showed that the information conveyed in gesture, but not in speech, embedded mental representations of action more deeply than action itself. Participants who had gestured while describing their solutions to the task had more difficulty in performing the task a second time when physical properties of the stimuli had been altered. Participants who performed the task a second time with unaltered stimuli showed not such difficulty. In this way gesture had created mental representations tied to action while action alone had not. See also Trofatter, et al (2014) for an expansion of this experiment.

All these studies lend support to the idea that abstract iconic and pointing gesture can itself be an influential and positive element in many cognitive tasks including mental transformation (Levine, Goldin-Meadow, Ehrlich, & Tran, 2009), geometry problem solving with pointing and tracing (Hu, Ginns, & Bobis, 2015), and conservation tasks (Church, Breckinridge, 1986; Ping & Goldin-Meadow, 2010; Ping, Raedy, 2008).

1.4 Pointing and Visuospatial Memory

Recent research looking at pointing independent of language and its impact on visuospatial memory adds to the evidence that pointing’s role in cognition is complex. Although Chum et al (2007) found that pointing at sets of visual stimuli and holding that information in working memory for a short time increased recognition task performance other research has demonstrated that pointing actually interferes with both recall and recognition. Chum et al used a paradigm in which each trial consisted of two spatial arrays in which shapes were presented sequentially on a white ground: one array was composed of circles and the other of squares. Participants were instructed to visually observe one of the arrays and to visually observe the other array while simultaneously pointing to the shapes on the touch screen. Dodd and Shumborski (2009) replicated and expanded Chum et al’s findings by showing that pointing aids memory when participants are asked to look at an array and point to another array in the
same experimental block. But, pointing did not prove beneficial when pointing and visual observation were performed in separate blocks. The authors proposed that one possible explanation for this may be that the selection of a subset of items that receives additional coding (vision and action) enhances memory as opposed to the passive coding of vision.

Rossi-Arnaud and colleagues (Rossi-Arnaud, Spataro, & Longobardi, 2012; Rossi-Arnaud, Spataro, & Marques, 2015) extended this line of research by focusing on the distinction between visual and spatial memory and how each is impacted by pointing. Rossi-Arnaud, et al (2012) showed that pointing hindered free recall in both blocked and mixed trials but with two important observations. When participants pointed first and then visually observed different arrays in the same block memory was hindered but when pointing was done after visual observation performance was significantly improved (as also found in Dodd & Shumborski, 2009). Additionally, pointing to larger arrays yielded better performance. In Rossi-Arnaud’s study (2012) participants were asked to look at arrays of red square targets in a matrix of black squares. Arrays were presented in either a point or no point condition and were immediately followed by a matrix of black, numbered squares in which participants recalled the locations of the red square targets. Rossi-Arnaud et al (2015) furthered these findings by testing pointing’s effect on visual and spatial memory. These results showed that pointing interfered in recall which calls upon spatial recollection resources that subsequently interfere with visual recognition. But, pointing was found to improve recognition performance when the time period between training and testing was longer, e.g. when the pause was for 5 seconds rather than 2 seconds. Although the sum of this research does show variation in performance in the pointing conditions relative to pointing time and target size, pointing results are always lower than visual observation results.

In the paradigms used by Chum, et al, Dodd and Shumborski, and Rossi-Arnaud results varied according to trial order, blocked or unblocked within subjects conditions, array size, and time between studying and testing. Based on their results there is a strong indication that action, whether it be a distracting action, a concrete action, or a gesture, interferes with the spatial coding of information but depending on experimental methodology and stimuli, can improve visual coding.
1.5 Goal of the Study

In several of the studies mentioned (Dodd & Shumborski, 2009; Hu et al., 2015; Rossi-Arnaud et al., 2012; Rossi-Arnaud et al., 2015) the pointing condition included touch, where participants not only pointed to targets but also simultaneously touched them. In the current study pointing does not include touch. Touch is only present in the Action condition. The aim of this study will be to evaluate the impact of pointing compared to action and visual observation on visuospatial memory using geometrical figures. The stimuli used will be composed of points with connected paths which would entail both a categorical and a coordinate encoding process (Rossi-Arnaud et al., 2015) such that the figures function as concrete forms and the dots function as fixed spatial locations. Moreover, we would like to test the idea that pointing is potentially beneficial for longer term memory tasks. To do this the time interval between studying and testing was 5 minutes focusing more on briefly holding information in memory than immediate memory output. Based on the above prior research we have mixed expectations. One the one hand, we expect that because pointing is an action that helps to encode information but interferes with spatial recall it should enhance performance in the recognition task and outperform both action and visual observation. On the other hand, since these memory tasks do not involve other cognitive learning skills such as reasoning or problem solving, pointing may have no effect on memory or may even act as an interference.

2. Method

Our goal in this experiment was to compare the effects of visual observation, action, and pointing on visuospatial memory. To meet this goal, in the Action Condition we asked participants to physically place felt dots on the vertices of the figures. In the Pointing Condition we asked participants to point towards the vertices of the figures.

2.1 Participants

Twenty-seven ($N = 27$; 22 females, 5 males) adult native Catalan speaking Universitat Pompeu Fabra students aged 18 – 29 ($M = 20.3$, $SD = 3.09$) participated in the study. Participants were predominantly Catalan-speaking and bilingual in Spanish. They reported a mean daily usage of Catalan of 72.38% ($SD = 18.27$%). The study was conducted in the Laboratori de Linguistica lab on campus. All participants submitted written consent prior to the study and were given monetary compensation of 5€ for their time.
2.2 Materials

The training materials were comprised of 15 geometrical figures composed of black lines and dots on a white ground (see Figure 1). The dots are connected by solid black lines to create concrete figures. Six of the figures are symmetrical and nine asymmetrical. The full set of 15 target figures was designed based on and expanded from stimuli used in studies investigating gesture and visuospatial memory (Hostetter, A., Alibali, M., 2010; Hostetter, A., Alibali, M., Kita, S. 2007).

Figure 1

<table>
<thead>
<tr>
<th>15 Target Figures</th>
</tr>
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<tbody>
<tr>
<td>![Figure 1]</td>
</tr>
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S = symmetrical | A = asymmetrical

2.3 Procedure

Each participant was trained and tested individually in the Laboratori de Linguistica lab (see Figure 2 for laboratory set-up).
In the Visual Observation condition the participant had seven seconds to observe the figure. In the Action condition the participant had seven seconds to place felt dots on the vertices of the geometrical figure. In the Pointing condition the participant had seven seconds to point to the vertices in the figure. We set the time limit of seven seconds based on the minimum time necessary to complete Action trainings. No specific instructions were given to participants regarding required amount of pointing time. The purpose of these conditions was to test their possible impact on memory. Five figures were presented in three sets of five figures (see Figure 1) according to three within-subjects conditions: Visual Observation (1), Action (2), and Pointing (3). Each training task was introduced by specific instructions. (see Figure 3 for training conditions).
• Condition 1
  - The figure is shown for 7 seconds and then covered with the curtain. During the 7 seconds the participant looks at the figure.
• Condition 2
  - The figure is shown for 7 seconds while the participant looks at and places dots on the figure. The figure is then covered with the curtain.
• Condition 3
  - The figure is shown for 7 seconds while the participant looks at and points to the locations of the vertices in the figure. The figure is then covered.

Prior to the training there was a pre-training session to familiarize the participant with the instructions in each condition. Each participant read the following instructions:

You are going to see three consecutive groups of five geometrical figures composed of lines and dots. There is a total of fifteen figures. You will have seven seconds to visually observe, point to, or place dots on each figure. First, we will practice each of the tasks: Practice 1: Visual observation, Practice 2: Place dots on figure, Practice 3: Point to dots on figure. At this point participants practiced each of the conditions once with three figures that were not included in the fifteen target figures. After the pre-training session participants read the following instructions to begin the training: Now we will present the fifteen geometrical figures. After the presentation of the fifteen figures we will ask you to remember as many of the figures as you can. Subsequently, instructions were given for each condition, for example, Visual Observation: We will now present five figures. You will have seven seconds to Visually Observe each figure.

There were 9 different training sets to ensure that all the figures were trained in all conditions in different orders across participants. After the training session, the participant filled out a language questionnaire for five minutes. Then the experimenter presented two memory tasks. First a free recall task (see Figure 4) was presented in which the participant attempted to recreate as many of the fifteen figures as possible by drawing them on paper within three minutes.
The participant then performed a one and a half minute recognition task (see Figure 5) in which the participant attempted to identify as many of the fifteen target figures as possible from an array of forty-five figures (15 targets, 30 foils). The total time for training and testing was approximately 25 minutes and all experiment sessions were video recorded.

2.5 Coding of Participant’s Responses

Responses to the free recall task were coded as correct (1) or incorrect (0). Correct drawings had the following features: identifiable as target figure, correct number of sides/vertices, as well as angles of lines, orientation, and proportions. A score of 0 was given for drawings that were not identifiable, did not have the correct number of sides/vertices, orientation, and proportions, or were missing. Although the coding of recall drawings required an element of subjective judgment (very few drawings were perfect copies of the targets and drawing skill varied between participants) drawings were reviewed several times to determine correct and incorrect figures.
Responses to the recognition task were coded as correct (1) or incorrect (0). An incorrect answer was either wrong figure selected or no figure selected.

To look more closely at the Pointing condition, pointing time was obtained by revisiting the experiment video for each participant. Pointing, whether used with speech or not, has four phases: the preparation phase, the gesture stroke, the gesture apex, and the retraction phase (McNeill, 1992). For this experiment pointing time started from the preparation phase of the gesture to the moment when the retraction phase began. Pointing times for all participants were divided into three groups 1) 2 seconds to 3.66 seconds, 2) 3.67s to 5.31s, 3) 5.32s to 7s.

3 Results

3.1 Performance on Free Recall and Recognition Tasks

All responses obtained (405 trials in total) were submitted to a Generalized Linear Mixed Model (GLMM), using IBM SPSS Statistics 21. Two GLMM models were run with overall performance across conditions in both the Free Recall and the Recognition tasks as a dependent variable (one model for each variable). The dependent variable was a numerical measure (1-right reply; 0–wrong reply) obtained by calculating the correct number of trials (15 in the Free Recall test and 15 in the Recognition test) from the participants’ responses in the Free Recall Test and the Recognition test respectively. The Fixed factor was Condition with three levels (Visual Observation, Action, and Pointing). Subjects and Items were set as random factors.

For Free Recall performance, the results showed a main effect of Condition (F(df = 447) = 20.196; p = .009). Paired comparisons between the (1)Visual Observation condition and the (2)Action and (3)Pointing conditions showed a statistically significant difference between Visual Observation and Action (p = .009), indicating that items accompanied by action were remembered the least. A significant difference between Visual Observation and Pointing was detected (p = .007). No significant difference between action and pointing was detected (p = .308).

For Recognition performance, the results showed a main effect of Condition (F(df = 447) = 5.869; p = .026). The paired comparisons between the (1)Visual Observation condition and the (2)Action and (3)Pointing conditions showed a statistically significant difference between Visual Observation and Action (p = .003) and Visual Observation and Pointing (p = .049); No significant difference between Action and Pointing was detected (p = .307).
3.2 Performance within the Pointing Condition

A GLMM was run to look at performance according to time spent pointing within the Pointing condition. There were no main effects in either the Free Recall task \( (p = 1) \) or the Recognition task \( (p = 1) \).

4 Discussion and Conclusions

In this study we looked at the effects of Action and Pointing on visual memory with a recognition task and on spatial memory with a free recall task. Pointing showed no significant effect in visuospatial memory performance in comparison to Action (in Free Recall: \( p = .308 \); in Recognition: \( p = .307 \)). Performance in both the Action and Pointing conditions showed a main effect with Visual Observation (in Free Recall: \( p = .009/.007 \); in Recognition: \( p = .003/.049 \)). This demonstrates that the effects of Action
and Pointing are very similar in this kind of task and appear to hinder memory considerably. Additional analysis of performance in the Pointing condition according to time spent pointing reveals no significant effect (in Free Recall: $p = 1$; in Recognition: $p = 1$).

Although we expected to see higher performance in Free Recall with Pointing the results show interference with both free recall and recognition. Both visual (e.g. Visual Observation) and spatial (e.g. Visual Observation / Action / Pointing) input can be coded in visuospatial memory as objects, locations, and kinesthetic information which is maintained in memory through subsequent imagistic rehearsal (Baddeley, 2007). This rehearsal, which is the visuospatial correlate to the phonological loop, can be disrupted by movement and/or planning for movement (Logie, 1995) which in turn disrupts memory. It is possible that having more than one visuospatial task in a condition (for example, action + visual observation in the Action condition) creates a situation in which each task competes for limited visuospatial resources resulting in interference and diminished memory processing. And, this may especially be the case when the competing tasks lack a cognitive component, such as language, abstraction, or problem solving, to relate input to specific and relevant outcomes or goals (Goldin-Meadow, 2010; McNeill, 1992).

When pointing was examined with time as a factor there was an indication, although not statistically significant, that more pointing improved performance. This is in parallel to Rossi-Arnaud’s studies (2012; 2015) which showed an effect of size of stimuli configurations: when participants pointed to larger sized configurations memory performance was better than smaller configurations. Taking this into account, the amount of time and/or quantity of pointing may merit further investigation.

It has been shown that the effect pointing, in conjunction with language, has on memory may depend on the task at hand (Cook, Yip, Goldin-Meadow, 2010; Goldin-Meadow, 2010; Hu et al., 2015) and, independent of language, on the experimental paradigm (Dodd & Shumborski, 2009; Rossi-Arnaud et al., 2012; Rossi-arnaud et al., 2015). Our findings are in line with this research and suggest ways in which the effects of pointing on memory may be further explored. For example, in the current study an important question to ask is what role did unspoken language on the part of the participant play in the encoding of information. Participants had five minutes between training and testing to utilize memory strategies that may have included visual chunking (Rossi-Arnaud et al., 2015) and/or the phonological loop (Baddeley, 2007). The ease with which the stimuli can be coded by participants could be an important factor in
memory storage. Features such as iconicity and symmetry in the figures may make such strategies more or less useful. Additional analysis of possible interactions that could be done in the current study might include checking for a recency effect and an effect of order (e.g., pointing before visual observation and vice versa). Future research into the role of pointing in memory and cognition might also include the role of vision in conjunction with action and pointing, the role of language, and the effects on long-term memory.

REFERENCES


