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Visual working memory in deaf children with diverse communication modes: Improvement by differential outcomes

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ABSTRACT

Although visual functions have been proposed to be enhanced in deaf individuals, empirical studies have not yet established clear evidence on this issue. The present study aimed to determine whether deaf children with diverse communication modes had superior visual memory and whether their performance was improved by the use of differential outcomes. Severely or profoundly deaf children who employed spoken Spanish, Spanish Sign Language (SSL), and both spoken Spanish and SSL modes of communication were tested in a delayed matching-to-sample task for visual working memory assessment. Hearing controls were used to compare performance. Participants were tested in two conditions, differential outcome and non-differential outcome conditions. Deaf groups with either oral or SSL modes of communication completed the task with less accuracy than bilingual and control hearing children. In addition, the performances of all groups improved through the use of differential outcomes.

1. Introduction

The "sensory compensation" hypothesis assumes that the loss of one sensory modality leads to compensation in other intact sensory modalities. Applied to deafness, the hypothesis predicts that deaf individuals may develop enhanced visual functions to compensate for lack of auditory input (Bavalier, Dye, & Hauser, 2006). Visual working memory could be one of these enhanced visual functions in deaf individuals. Generally speaking, working memory (WM) refers to the capacity-limited ability to maintain and manipulate information relevant to an ongoing task (Boutla, Supalla, Newport, & Bavelier, 2004). Most theoretical views of WM assume that WM is not a single store or structure; rather, WM can be split into several subdivisions or components. According to one of the most influential models of WM, working memory comprises at least three components: a central executive and two storage systems—a phonological loop and a visuospatial sketchpad (Baddeley, 2003; Baddeley & Hitch, 1974). In this model, the phonological loop is responsible for the storage and maintenance of information in phonological form, and the visuospatial sketchpad maintains visual and spatial information; both storage systems are controlled by the central executive, a control system of limited attentional capacity responsible for the manipulation of information within WM (Repovs & Baddeley, 2006). In recent years, this initial model has been reformulated in the light of empirical data. For example, double dissociations from neuropsychological and behavioural studies indicate the need to distinguish between visual and spatial memory within the visuospatial sketchpad (Baddeley, 2003).

Although an important amount of research has studied the functioning and characteristics of phonological WM in deaf children, less attention has been paid to visuospatial WM in deaf individuals. Whereas several studies have shown that deaf

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native signers outperform non-signers on different spatial WM tasks (see Keehner & Atkinson, 2006, for a review), no evidence for the existence of superior visual memory in this population has been found in empirical studies of visual WM (Kyle & Harris, 2006; Parasnis, Samar, Bettger, & Sahte, 1996). However, these results should be considered with caution. To our knowledge, studies of visual WM in deaf children have employed serial recall paradigms. Similarly to a phonological span test, these paradigms present a series of pictures that the participant has to recall immediately after the last item presentation (see, for example, MacSweeney, Campbell, & Dolan, 1996). Todman and colleagues have shown that deaf children outperform hearing children when stimuli are presented simultaneously, as opposed to stimuli presented sequentially (Todman & Cowdy, 1993; Todman & Seedhouse, 1994). Therefore, the mere use of serial recall paradigms can lead to unrealistic conclusions about the capacities of deaf children. The results may be also confounded by the use of phonological coding. For example, some degree of phonological coding of pictures was demonstrated by the study of MacSweeney et al. (1996) finding that (a) an articulatory suppression task (repeating the irrelevant-to-the-task word "because, because, etc.) interfered with the recall of a series of pictures and (b) phonologically similar pictures lead to a poorer performance in deaf youngsters. Moreover, despite the claims that communication mode can shape the development of WM in deaf children (Keehner & Atkinson, 2006), the literature is scarce in studies comparing different communication modes, and the studies conducted on the topic have found no evidence of different WM characteristics between deaf with different communication backgrounds (Koo, Crain, LaSasso, & Eden, 2008; Miller, 2001).

A procedure that may overcome the difficulty of deaf children with sequentially presented stimuli is a delayed matching-to-sample task (DMTS). DMTS tasks have been used extensively in the study of WM in both non-human and human subjects (Paule et al., 1998). The basic procedure requires the subject to view a sample stimulus for a period of time and, after a delay, the subject is presented with one or more choice or comparison stimuli. The task of the subject is to select the comparison stimulus that matches the sample stimulus. No easily nameable stimuli can be used as stimuli on the task in order to avoid the confounding effects of the phonological coding of the stimuli.

Some recent studies have found that introducing a small procedural change in DMTS tasks can lead to a better memory performance on the task. Usually, all correct choices on these tasks are followed by the same feedback or outcome. Instead, if each correct choice is followed by a unique and different outcome, performance is improved compared to procedures employing the same outcome or to procedures administering outcomes randomly. This procedure has been termed the Differential Outcomes Procedure (DOP) and its efficacy has been shown with animals (Brodigan & Peterson, 1976) and with human subjects with and without memory deficits (Hochhalter, Sweeney, Bakke, Holub, & Overmier, 2000; López-Crespo, Plaza, Fuentes, & Estévez, 2009; Plaza, Estévez, López-Crespo, & Fuentes, 2011).

The present study has two purposes: first, to determine whether deaf children with diverse communication modes have superior visual memory assessed through a DMST task and second, to determine whether the participants of the study take advantage of the use of differential outcomes.

2. Method

2.1. Participants

Fifty children took part in this study, 30 of them were severely or profoundly deaf children (mean age 11.3 ± 0.24 years) and 20 were hearing controls matched in age (mean age 11.1 ± 0.17). The deaf children employed diverse communication modes: 10 of them used spoken Spanish to communicate, 9 used Spanish Sign Language (SSL) and 11 were bilinguals (that is, they employed both spoken Spanish and SSL modes of communication). Twelve children had cochlear implants. All deaf participants were drawn from a special school and from two associations for parents of deaf children. Hearing children were recruited from a public school. Participants' parents/tutors provided a written informed consent prior to testing.

2.2. Apparatus

A computerized version of a DMTS task for visual WM assessment was created using E-Prime 1.1 (Psychology Software Tool, Pittsburgh, PA). The stimuli used for testing consisted of 6 Kanji symbols measuring 2×1.7 cm and 6 drawings of smiling faces measuring approximately 7×5 cm (see Fig. 1 for an example). The Kanji stimuli served as sample and comparison stimuli. The smiling faces served as outcomes for correct answers. All stimuli were displayed on the centre of a 15 in. (38 cm) colour laptop monitor with a Pentium processor.

2.3. Procedure

All participants were tested individually. Participants performed the DMTS task in a quiet room. They sat at a table facing the laptop screen placed at a distance of approximately 50 cm. Instructions were administered to the participants in their preferred language/communication mode by a hearing research assistant who was fluent in spoken Spanish and SSL. The experiment consisted of a DMTS task comprising 48 trials grouped into two blocks of 24 trials each. The trial sequence (see Fig. 1) began with a fixation cross presented for 1000 ms. The cross was replaced by a white screen for 500 ms and then a Kanji letter (the sample stimulus) appeared on the centre of the screen for 1500 ms. Each of the six sample stimuli was repeated four times per block (eight times in total). A white screen lasting 0 or 4 s, randomly selected, replaced the sample