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Mixed-handedness advantages in episodic memory obtained under conditions of intentional learning extend to incidental learning

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ABSTRACT

The existence of handedness differences in the retrieval of episodic memories is well-documented, but virtually all have been obtained under conditions of intentional learning. Two experiments are reported that extend the presence of such handedness differences to memory retrieval under conditions of incidental learning. Experiment 1 used Craik and Tulving's (1975) classic levels-of-processing paradigm and obtained handedness differences under incidental and intentional conditions of deep processing, but not under conditions of shallow incidental processing. Experiment 2 looked at incidental memory for distracter items from a recognition memory task and again found a mixed-handed advantage. Results are discussed in terms of the relation between interhemispheric interaction, levels of processing, and episodic memory retrieval.

1. Introduction

The existence of individual differences in the retrieval of episodic memories as a function of degree of handedness is well documented. Mixed (or inconsistent) handedness, relative to strong (or consistent) handedness, is associated with superior recall of lab-based and real world-based memories (Parker & Dagnall, 2010; Propper, Christman, & Phaneuf, 2005), superior source memory (Christman, Propper, & Dion, 2004; Lyle & Jacobs, 2010; Lyle, Logan, & Roediger, 2008; Lyle, McCabe, & Roediger, 2008), an increased tendency for recognition to be accompanied by recollection, as indexed by "Remember" judgments, versus familiarity, as indexed by "Know" judgments (Propper & Christman, 2004), and an earlier offset of childhood amnesia (Christman, Propper, & Brown, 2006). There is also tentative evidence linking mixed-handedness to a higher capacity episodic buffer in working memory (Kempe, Brooks, & Christman, 2009), a decreased tendency to experience dissociative amnesia (Christman & Ammann, 1995), and better self-reported everyday memory (Christman & Propper, 2008).

These findings have been interpreted in terms of two related phenomena. First, strong right-handedness is associated with smaller corpus callosum size (e.g., Clarke & Zaidel, 1994; Cowell, Kertesz, & Denenberg, 1993; Habib et al., 1991; Witelson & Goldsmith, 1991), suggesting decreased interhemispheric interaction in strongly right-handed individuals. Moreover, behavioral evidence indicates that strong right-handedness is associated with decreased functional interaction between processes known to be lateralized to the opposite hemispheres, including left hemisphere-based belief maintenance and right hemisphere-based belief updating mechanisms (e.g., Christman, Bentle, & Niebauer, 2007; Christman, Henning, Geers, Propper, & Niebauer, 2008; Niebauer, Aselage, & Schutte, 2002; Niebauer, Christman, Reid, & Garvey, 2004), left hemisphere-based approach and right hemisphere-based withdrawal mechanisms (Christman, Jasper, Sontam, & Cooil, 2007), and left hemisphere-based word reading and right hemisphere-based color processing mechanisms (Christman, 2001).

The second relevant phenomenon involves a between-hemisphere division of labor in episodic memory, with fMRI studies indicating that the left hemisphere is more involved in encoding than retrieving episodic memories, and vice versa for the right hemisphere (e.g., Cabeza & Nyberg, 2000; Habib, Nyberg, & Tulving, 2003; Tulving, Kapur, Craik, Moscovitch, & Houle, 1994). Similarly, a recent study using transcranial magnetic stimulation found that disrupting left versus right prefrontal activity was more detrimental to the encoding versus retrieval of episodic memories, respectively (Gagnon, Blanchet, Grondin, & Schneider, 2010). Thus, to the extent that strong right-handedness is associated with decreased interhemispheric interaction and episodic memory is associated with interaction between left hemisphere-based encoding and right hemisphere-based retrieval, the findings of inferior episodic memory in strong right-handers have been hypothesized to reflect decreased interhemispheric interaction.

The majority of the literature on handedness differences in episodic memory has focused on conditions involving intentional

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learning (i.e., participants knew their memory for material would be subsequently tested). The only exceptions are studies demonstrating handedness differences in childhood amnesia (Christman et al., 2006), real world-based memories (Propper et al., 2005), and incidental memory for slideshows (Lyle & Jacobs, 2010). However, these were not experimentally controlled examples of incidental learning (e.g., they did not manipulate the nature of the orienting task during encoding). The present paper presents an initial investigation into potential handedness differences in episodic memory under various conditions of incidental as well as intentional learning, in order to test the generality of the mixed-handed advantage in episodic memory.

In addition, the current experiments can address the question of the extent to which the mixed-handed advantage arises at the encoding versus retrieval stages. While past research has been interpreted in terms of mixed-handers' greater access to right hemisphere-based *retrieval* mechanisms, it is possible that the observed handedness differences arise at least in part from superior *encoding* in mixed-handers. Under conditions of intentional learning, perhaps mixed-handers spontaneously engage in relatively deeper levels of processing, leading to their observed memory advantage, while under conditions of incidental learning, perhaps mixed-handers will *not* spontaneously engage in deeper levels of processing than strong right-handers, and the mixed-handed advantage would be attenuated or eliminated. Conversely, if the memory advantage for mixed-handers is based on superior retrieval processes, it should extend to conditions of incidental learning.

Experiment 1 is based on the classic levels of processing effect demonstrated by Craik and Tulving (1975), in which intentional learning was compared to incidental learning under conditions of shallow versus deep processing. The second experiment is based on the procedure developed by Buckner, Wheeler, and Sheridan (2001), in which participants are first given a standard recognition memory test, and are then tested for their incidental memory for distracter items from the initial recognition test.

2. Experiment 1

2.1. Participants

Participants consisted of 182 undergraduate students from the University of Toledo who received credit in a psychology course for their participation. Handedness was assessed by use of the Edinburgh Handedness Inventory (EHI; Oldfield, 1971). The median value for the sample on the EHI was 80. Following past practice of studies comparing strong- versus mixed-handedness (Christman et al., 2004, 2006, 2008; Christman, Bentle, et al., 2007; Christman, Jasper, et al., 2007; Lyle, Logan, et al., 2008; Lyle, McCabe, et al., 2008; Parker & Dagnall, 2010; Propper & Christman, 2004; Propper et al., 2005; Sontam & Christman, in press; Sontam, Christman, & Jasper, 2009), a median split was performed, dividing the sample into 75 mixed-handers (with EHI scores ranging from −75 to +75) and 104 strong right-handers (EHI scores of +80 or higher); the data for three strongly left-handed participants (EHI scores of −80 or lower) were excluded from analyses. While the current framework argues that degree of handedness (mixed versus strong) is more important than direction (left versus right), there is still evidence that strong left- and strong right-handers differ from one another (Christman & Ammann, 1995; Propper, Christman, & Olejarz, 2007). It is worth noting, however, that post hoc analyses in which the strong left-handers are included with the strong right-handers yield the same basic pattern of results as when the strong left-handers are excluded. In terms of sex, the final sample included 115 females and 64 males.

Participants were randomly assigned to one of the four encoding conditions by the computer. Of 179 total participants, 37 (17 mixed-handed, 20 strong-handed) were assigned to the structural encoding condition, 48 (22 mixed-handed, 26 strong-handed) to the phonemic encoding condition, 48 (18 mixed-handed, 30 strong-handed) to the semantic encoding condition, and 46 (17 mixed-handed, 29 strong-handed) to the intentional encoding condition.

2.2. Materials

The stimulus materials were presented on a Power Macintosh computer with a 17″ CRT monitor. Stimuli were presented under the control of the Reaction Time module of the MacLaboratory program v.3.0.2. Stimulus materials were adapted directly from those employed by Craik and Tulving (1975), and consisted of 24 concrete words of moderate to high frequency. The orienting questions used in the incidental learning conditions were also adapted directly from Craik and Tulving (1975).

2.3. Procedure

Participants were tested individually and informed they would be taking part in a study of word perception. After an informed consent sheet was signed, handedness was assessed using the EHI. Participants were then seated at the computer, which displayed instructions for completing the word trials. Encoding in the structural, phonemic, and semantic conditions involved incidental learning, so participants were not informed their recall of the words would be tested later. Participants in the intentional condition were informed that they would be later tested for their memory for words presented. The computer displayed a series of 24 words in random order and asked participants to make judgments after each was presented.

Participants in the structural condition were asked whether each word was printed in uppercase letters. Participants in the phonemic condition were asked whether each word rhymed with another target word. Participants in the semantic condition were asked whether each word fit a particular sentence frame. Finally, participants in the intentional condition were asked to study each word and attempt to remember it using any strategy they preferred and were reminded they would be tested on their recall later. Each question in the incidental learning conditions was in a 'yes' and 'no' format, with the correct answer to half of the questions being 'yes' and the other half 'no'. In the incidental encoding conditions, the computer displayed the question for 2 s, then the target word appeared for five additional seconds, and participants answered by pressing the appropriate key. The computer recorded reaction time. Response key assignment was counterbalanced. In the intentional encoding condition, words were simply displayed on the computer screen for 5 s each while participants studied them.

To minimize possible recency effects, participants were given a mandatory 5-min break following the word judgments where they were asked to sit quietly and relax. The experimenter then informed the participants in the incidental learning conditions that they were to take a surprise recall test that required writing down as many words presented by the computer as they could remember. The intentional encoding condition shared an identical method except participants were already aware of the final memory test.

3. Results

The dependent variables were the number of words correctly recalled in each condition, the number of words incorrectly