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The role of verbal labels on flexible memory retrieval at 12-months of age

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Abstract
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ABSTRACT

The provision of verbal labels enhances 12-month-old infants' memory flexibility across a form change in a puppet imitation task (Herbert, 2011), although the mechanisms for this effect remain unclear. Here we investigate whether verbal labels can scaffold flexible memory retrieval when task difficulty increases and consider the mechanism responsible for the effect of language cues on early memory flexibility. Twelve-month-old infants were provided with English, Chinese, or empty language cues during a difficult imitation task, a combined change in the puppet's colour and form at the test (Hayne et al., 1997). Imitation performance by infants in the English language condition only exceeded baseline performance after the 10-min delay. Thus, verbal labels facilitated flexible memory retrieval on this task. There were no correlations between infants' language comprehension and imitation performance. Thus, it is likely that verbal labels facilitate both attention and categorisation during encoding and retrieval.

1. Introduction

The ability to flexibly retrieve our memories across a range of situations is an important feature of the declarative memory system. Memory flexibility, or the ability to use pre-existing stores of knowledge to solve new problems, enables us to avoid costly or time consuming re-learning and to benefit from our past experiences. Across the first two years of life, studies using the deferred imitation procedure have demonstrated that the ability to flexibly retrieve memories across changes in the social and physical contexts, or changes in the target stimulus develops gradually (e.g., Hayne, Boniface, & Barr, 2000; Hayne, Barr, & Herbert, 2003; Hayne, MacDonald, & Barr, 1997; Herbert & Hayne, 2000a; Herbert, Gross, & Hayne, 2006; Learmonth, Lamberth, & Rovee-Collier, 2004; Learmonth, Lamberth, & Rovee-Collier, 2005). For example, within the puppet imitation task, 12-month old infants can reproduce the target actions shown on a puppet that differs in colour (Hayne et al., 1997) or form (Jones & Herbert, 2008) from the one present during the original demonstration after a 10 min delay, but not with a puppet that differs in both colour and form, or after a 24 h delay. In contrast, 18-month old infants can reproduce the target actions with a puppet that differs in both colour and form after a 24-h delay but not when the puppets are highly

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dissimilar (e.g., black/white cow, yellow/orange duck; Hayne et al., 1997). Thus, early memory flexibility appears to be determined in part, by the degree of changes to the central stimulus between learning and retrieval, and the length of the retention interval (also see Herbert & Hayne, 2000a).

Language cues have recently been identified as a powerful means by which to enhance flexible memory retrieval at young ages. Being able to spontaneously self-generate a label for a novel stimulus or a hiding location facilitates 2-year-old children's ability to transfer knowledge to a new situation (Miller & Marcovitch, 2011; Zimmermann et al., 2015), while memory flexibility at younger ages benefits from experimenter-generated labels (Herbert & Hayne, 2000; Herbert, 2011). For example, in Herbert (2011), 12- and 15-month old infants were shown the target actions with the puppet task accompanied by verbal labels for the object and actions (e.g., "Look, a puppet. Off. Shake. On") or no label during the demonstration. At the test 10 min later, the puppet was labelled again for infants in the verbal label condition only. Infants in both the label and no label conditions reproduced significantly more target actions with a puppet that differed in form (e.g., pale grey mouse at demonstration, pale grey rabbit at test) than baseline performance by infants in the control condition. Thus, infants were already showing some ability to generalise across a change in stimulus form after the short delay. Importantly, however, infants in the label condition reproduced significantly more target actions than infants in the no label condition. In other words, verbal labels enhanced performance above spontaneous flexible memory retrieval. Whether the same effect would be observed when task difficulty increases remains to be determined. Perhaps unsurprisingly, verbal labels do not facilitate infant abilities in all situations, such as when 15-month-olds are asked to transfer knowledge across a complex 2D to 3D action imitation task (Zack, Gerhardstein, Meltzoff, & Barr, 2013). However a unique feature of the puppet task is that task difficulty can be progressively increased by altering the colour, form, or colour and form of the puppet, providing an opportunity to examine the limits of the facilitative effects of language on infant memory abilities. In this study we consider whether verbal labels can facilitate infants' memory flexibility across a complex change, altering both the form and colour of the stimulus present at retrieval.

Although the body of research showing the facilitative effects of language cues on memory flexibility continues to grow, the mechanism for this effect remains unclear. One possibility is that verbal labels may facilitate flexible memory retrieval across changes in the target object by potentially facilitating categorisation of the target and test objects (for similar argument, see Jones & Herbert, 2009). Infant language comprehension begins around 8- to 10-months (Fenson et al., 1994) at which point verbal labels can influence categorisation (Westermann & Mareschal, 2014). Verbal labels can affect perceived object similarity and can help infants categorise perceptually dissimilar exemplars of objects into a single category (Plunkett, Hu, & Cohen, 2008; Waxman & Booth, 2003; Waxman & Braun, 2005). For example, Plunkett et al. (2008) presented 10-month old infants with a series of objects that differed on a number of features where values on one dimension could combine with the full range of values on other dimensions. Infants categorised the objects into two categories (long neck and short neck) shown by a visual preference for the object that averaged across all dimensions. In contrast, when given a single novel label (e.g., "dax") for the objects during the familiarisation phase, 10-month old infants categorised objects into a single category (Plunkett et al., 2008). Thus, in the imitation task, a label presented at demonstration and test may help infants form a single category for the demonstration and test puppets and facilitate memory retrieval across the stimulus change.

Alternatively, verbal labels may function to direct infant's attention to the relevant aspects of the learning task. Indeed, Taylor and Herbert (2014) found that 6-, 9- and 12-month old infants' attentional patterns during the puppet demonstration session were related to their ability to reproduce the target actions at test. Using an eye-tracker, Taylor and Herbert (2014) showed that infants distribute their attention more widely than adults when viewing the puppet task. Critically, greater attention to the person and less attention to the background were related to learning outcome on the task (Taylor & Herbert, 2014). Furthermore, studies have shown that 9- to 12-month old infants increase attention to objects that have been labelled compared to objects that have not (Balaban & Waxman, 1997; Baldwin & Markman, 1989). Thus, verbal labels may serve as an attention grabber during learning and at test.

The purpose of the present experiment was to determine whether verbal labels facilitate flexible memory retrieval via an attentional or categorisation mechanism. Twelve-month old infants were presented with a puppet that differed in both colour and form during the imitation test session following a live demonstration 10 min earlier. At this age, infants typically fail to reproduce the target actions when presented with a colour and form change puppet (Hayne et al., 1997). Some infants received *empty language* cues (no verbal label) whilst others received *language* cues (verbal label for object and actions) in either English or Chinese. The English language labels were used to determine whether language could scaffold learning and push infants into succeeding on the difficult flexible retrieval task. By 12-months of age infants can no longer discriminate between foreign-language phonetics (Best, McRoberts, LaFleur, & Silver-Isenstadt, 1995; Kuhl, Tsao, & Liu, 2003; Maye, Werker, & Gerken, 2002; Narayan, Werker, & Beddor, 2010; Werker & Tees, 1984) and mouth sounds alone are not sufficient to produce categorisation (Fulkerson & Haaf, 2003). Thus, the Chinese language labels were used to determine whether verbal information merely directs infant attention to the relevant aspects of the task.

We hypothesised that infants who receive *empty language* cues will fail to reproduce the target actions with the form and colour change puppet, consistent with prior work (Hayne et al., 1997). In contrast, we predicted that infants who receive *English language* cues would reproduce the target actions with the form and colour change puppet, consistent with both an attentional and categorisation mechanism. If infants in the *Chinese language* group do not perform above baseline then the categorisation mechanism will be supported. In contrast, if infants in the *Chinese language* condition do perform above baseline then the attentional mechanism will be supported. If the effectiveness of verbal labels can be explained by

Table 1
Chinese phrases used in the warm-up session in the Chinese language condition.

English Phrases	Chinese Pronunciation	Chinese Characters
Can you do this?	Ni Hui Ma	你会吗
Here you are.	Gei Ni	给你
Clever boy/girl!	Zhen Cong Ming	真聪明

categorisation, then infants' language comprehension should be related to their subsequent imitation when given *English language* cues (e.g., Waxman & Booth, 2003).

2. Method

2.1. Participants

Participants were 52 12-month old infants (26 males, 26 females) tested within 10 days of their birthday. None of the infants were born more than four weeks premature or experienced birthing difficulties. An additional 15 infants were tested but excluded due to infant fussiness ($n = 6$), failure to touch the puppet during the test ($n = 2$), experimenter error (n = 4) and previous exposure to a foreign language (n = 3).

2.2. Measures

The Oxford Communicative Development Index (Oxford CDI; Hamilton, Plunkett, & Schafer, 2000) was used to measure infant vocabulary comprehension and production. Comprehension scores around 15% and production scores around 0% are considered typical for 12-month old British infants (Hamilton et al., 2000).

2.3. Stimuli

Four hand puppets were used in the present study; two resembling a mouse and two resembling a rabbit, both made in either pale grey or pastel pink (see Hayne et al., 1997). The puppets were 30 cm in height and had a removable mitten 8 cm (w) × 9 cm (h) in matching pale grey or pastel pink on the puppet's right arm. A large jingle bell was attached to the inside of the mitten during the demonstration for the experimental conditions, and attached to the back of the puppet for the control condition (see Hayne et al., 1997).

2.4. Procedure

All infants were tested individually in the Developmental lab at the University of Sheffield. Upon arrival, the purpose of the study was explained to caregivers and informed consent was obtained. Infants were randomly assigned to one of four conditions: an *English language* condition ($n = 14$), a *Chinese language* condition ($n = 12$), an *empty language* condition ($n = 12$) and a *control* condition ($n = 14$). Half of the infants in each condition were female and half were male.

Following consent, all infants engaged in a warm-up session in the waiting room with the experimenter until a smile was elicited. A native Chinese speaker conducted the *Chinese language* condition and a native English speaker conducted the *English language* and *empty language* conditions, both experimenters conducted the *control* condition. Infants in the *Chinese language* condition were exposed to three short Chinese phrases during the warm-up session (see Table 1); the same phrases were also given in English to the infants in the *English language*, *empty language* and *control* conditions. The purpose of exposure to Chinese phrases prior to the experiment was to build up the infant's familiarity to hearing the experimenter speak in a foreign language. During the warm up session, the parent filled out the Oxford CDI. Parents in the *Chinese language* condition also answered two questions about the infant's language exposure (Has your baby ever been exposed to Chinese language before e.g., neighbours, friends? Has your baby ever been exposed to any other languages except English?). After the warm up session, the experimenter then escorted the caregiver and infant to a separate testing room.

2.4.1. Demonstration Session

Infants were seated on their caregiver's lap, with the experimenter kneeling on the floor facing the infant. During a warm up phase, the experimenter interacted with the infant until he or she appeared comfortable. Out of view of the infant, the experimenter placed the demonstration puppet on her hand. The puppet was then placed in front of the infant, out of reaching distance. For infants in the *English language, Chinese language* and *empty language* conditions, the experimenter performed three actions on the puppet: 1) taking the puppet's mitten off, 2) deliberately shaking the mitten three times in succession ringing the jingle bell attached inside, and 3) replacing the mitten back on the puppet. This demonstration was accompanied by *English language, Chinese language* or *empty language* spoken by the experimenter (see Table 2). Verbal

Table 2
The language given by the experimenter as a function of experimental condition and the action being demonstrated with the stimuli.

	English Language	Chinese Language		Empty Language & Control
		Chinese Pronunciation	Chinese Characters	
Revealing the Demonstration Puppet	Look, a puppet	Kan Wa Wa	看，娃娃	Look
Take the mitten off	Off	Na Xia Lai	拿下来	–
Shake the mitten	Shake	Yao Yi Yao	摇一摇	–
Put the mitten back on	On	Dai Hui Qu	戴回去	–
Revealing the Test Puppet	Look, a puppet	Kan Wa Wa	看，娃娃	Look

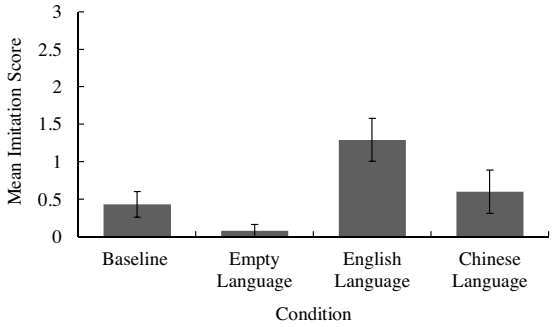

Fig. 1. Mean imitation score (+/− 1 SE.) as a function condition.

labels in the *empty language* condition were limited to "Look" and filler phrases in between each repetition in order to limit attention-grabbing cues. This enabled us to consider the role of verbal labels in directing attention during the task in the *Chinese language* and *English language* conditions. The actions were repeated three times in succession before the puppet was removed from view. For infants in the *control* condition, the experimenter shook the puppet side to side three times and repeated the action three times in succession accompanied by empty language cues. The purpose of the control group was to measure infants' spontaneous production of the target actions. For all conditions, the experimenter said "Shall we do that again" or "Are you watching" in between each repetition. The colour and form of the demonstration puppet was counterbalanced across infants.

2.4.2. Test Session

The test session was conducted approximately 10 min after the demonstration. During the 10-min delay, the infant, caregiver, and experimenter interacted in the waiting room with unrelated toys. Each infant then returned with their caregiver to the experimental room and was presented with the form and colour change puppet during the test session (e.g., pastel pink rabbit during the demonstration session, pale grey mouse during the test session). The puppets were counterbalanced across condition. The experimenter placed the test puppet on her hand, out of view of the infant. The experimenter then revealed the puppet, which she either labelled (*English language, Chinese language*) or simply said, "Look" (*empty language* and *control*), before placing the puppet within reaching distance of the infant. Infants were then given 90 s to produce the target actions, timed from their first touch. The entire session was videotaped for later analysis.

3. Results

The videotaped test sessions were coded for the presence or absence of the target actions and infants were given an imitation score based on the number of target actions produced (range 0–3). Approximately 23% ($n = 12$) of the videos were double coded by an independent experimenter. Inter-observer reliability analysis was 83% (kappa = 0.72). Preliminary analyses revealed no effect of gender on imitation scores so the data was collapsed across gender for subsequent analyses.

To determine whether there were differences in infants' imitation scores as a function of condition, a Kruskal-Wallis test was conducted due to differences in sample size and variance across condition and the control, empty language and Chinese language conditions violating the normality assumption. Overall, there was a significant effect of condition on infant imitation scores, $H(3) = 12.93$, $p = 0.002$ (see Fig. 1). In deferred imitation studies, memory is inferred if the imitation score in a demonstration condition exceeds the spontaneous production of target actions produced by infants in the baseline control condition (see Hayne, 2004; Meltzoff, 1985). Given that the imitation scores were not normally distributed, Mann-Whitney tests were used to compare each experimental group (English language, empty language, Chinese language) to the spontaneous production of the target actions in the control group. The English language group reproduced the target

Table 3
Mean score (S.D.) for infant language comprehension and production expressed as a proportion of the total number of words on the CDI as a function of experimental group.

Condition	N	Mean scores (S.D.)% Mean percentile rank CDI: Comprehension	CDI: Production
Control	12	13.35 (9.06) 50.01%	1.62 (3.09) 45.58%
Empty Language	12	19.37 (26.24) 51.28%	1.88 (2.65) 54.40%
English language	14	29.01 (29.63) 64.80%	2.90 (5.44) 49.16%
Chinese Language	12	15.00 (12.29) 50.60%	2.24 (3.79) 51.04%

actions significantly more than the control group ($U = 52.00$, $p = 0.035$, $r = -0.43$). In contrast, the empty language ($U = 60.50$, $p = 0.231$, $r = -0.32$) and Chinese language ($U = 79.00$, $p = 0.820$, $r = -0.06$) groups did not differ significantly from the control group. Thus, only infants in the English language group reproduced the target actions above spontaneous production by infants in the control group.

For the CDIs, data was missing for two infants whose parents did not complete and return the questionnaire. Children were given total scores for the number of words that the child comprehends and the number of words that the child produces. These scores were calculated by summing the number of items that the caregiver had marked as "understands" or "understands and says" for the comprehension score and the number of items that the caregiver had marked as "understands and says" for the production score. Children's comprehension and production scores were expressed as a percentiles according using the norming data for the Oxford CDI (Hamilton et al., 2000) for analysis.

Preliminary analyses revealed a significant effect of gender on vocabulary comprehension scores $t(48) = 2.15$, $p = 0.037$ with girls ($m = 63.11$, $sd = 32.12$) scoring more highly than boys ($m = 46.08$, $sd = 23.13$). There was no significant effect of gender on vocabulary production $t(48) = 1.49$, $p = 0.144$ (girls $m = 56.00$, $sd = 32.87$; boys $m = 44.02$, $sd = 23.30$). Given that there was an even gender split in each condition, the data was collapsed across gender for subsequent analyses. To determine whether vocabulary comprehension or production differed between infants in each condition, Kruskal-Wallis tests were conducted. Overall, there was no significant difference in vocabulary comprehension, $H(3) = 2.431$, $p = 0.488$ or vocabulary production, $H(3) = 0.485$, $p = 0.922$ between infants in each experimental condition (see Table 3). In addition, Kendall's tau analyses revealed non-significant correlations between vocabulary comprehension or production scores and imitation scores for any condition.

4. Discussion

The present experiment replicates and extends prior work (Hayne et al., 1997) in demonstrating that 12-month old infants fail to retrieve their memories if the stimulus presented during the test session differs in both colour and form from the one present during encoding, even after a short delay. Moreover, consistent with our hypothesis, the addition of experimenter provided language cues did facilitate flexible memory retrieval across the form and colour change stimulus in the present study. While there are limits on their effectiveness (see Zack et al., 2013), verbal cues can scaffold learning and push infants into succeeding on a difficult flexible retrieval task.

To start to tease apart the attentional and categorisation mechanisms by which verbal cues facilitate flexible memory retrieval, it is particularly informative to consider the results from the Chinese language condition. The addition of Chinese language labels during the demonstration and test did not facilitate infants' flexible memory retrieval above the spontaneous production of the target actions by the control group. Given that by 12-months of age infants can no longer discriminate between foreign-language phonetics (Best et al., 1995; Kuhl et al., 2003; Maye et al., 2002; Narayan et al., 2010; Werker & Tees, 1984), our monolingual English infants will not have been able to comprehend the Chinese verbal labels. Furthermore, infants fail to categorise following non-labelling mouth sounds (Fulkerson & Haaf, 2003). Instead, the Chinese verbal labels should serve as an attention-grabber. Thus, the results from Chinese language condition suggest that an attentional mechanism alone is unlikely to explain how verbal labels influence memory retrieval.

There was no association between vocabulary comprehension or production at 12-months of age on imitation performance by infants in any condition. It is important to note that the Oxford CDI does not measure children's comprehension of the words "puppet" or "shake" thus we do not have a validated record of whether infants understood the specific words used in our narration. Anecdotally, after the task, parents frequently stated they did not use these types of words with their infants. However, regardless of whether our infants benefited from the specific words used in the narration, it remains a possibility that categorisation may be the mechanism by which verbal cues facilitate flexible memory retrieval. A considerable body of research has shown that vocabulary comprehension is not essential for categorisation. For example, even before an age at which they can parse individual words (Jusczyk & Aslin, 1995), 3- and 4-month old infants categorise pictures of animals following verbal labels but not tones (Ferry, Hespos, & Waxman, 2010). The null finding for the Chinese language group appear to rule out phonetic discrimination as a potential mechanism for categorisation but not comprehension as a mechanism for categorisation. However, it is likely that verbal labels will facilitate both attention and categorisation during

encoding and retrieval. Using eye tracking to monitor infants visual attention during an imitation demonstration session when verbal labels are given will help determine whether attention is one mechanism by which verbal labels can enhance flexible memory retrieval (also see Taylor & Herbert, 2014).

In conclusion, the present results, combined with those of Herbert (2011), suggest that verbal labels can facilitate infants' emerging memory flexibility, even as the task becomes progressively more difficult. The next steps in this research will be to determine the relationship between memory flexibility, language cues, and forgetting. Infants' ability to flexibly retrieve their memories is influenced by the length of the retention interval between the demonstration and test sessions (e.g., Hayne et al., 1997; Herbert & Hayne, 2000a, 2000b). Moreover, prior work has demonstrated that verbal labels can facilitate the length of time over which a memory can be retained when the test stimuli are the same as those presented during the demonstration (Hayne & Herbert, 2004). Thus, it remains to be determined whether verbal labels can scaffold flexible memory retrieval across longer delays, or whether longer retention intervals are also a task demand too far for the early verbal infant.

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