Short Report

Comparing Sign Language and Speech Reveals a Universal Limit on Short-Term Memory Capacity

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Short-term memory (STM) for signs in native signers consistently shows a smaller capacity than STM for words in native speakers (see Emmorey, 2002, for review). One explanation of this difference is based on the *length effect*: Short items yield higher spans than items that take longer to pronounce, presumably because of limited processing time. Signs in American Sign Language (ASL) take longer to articulate than English words (Bellugi & Fischer, 1972). This is not problematic in natural language use, because ASL conveys information simultaneously. However, with immediate serial recall, articulation time looms large.

Some researchers have argued that articulation time is sufficient to account for the sign-speech difference in STM (Emmorey, 2002; Marschark & Mayer, 1998; Wilson, 2001; Wilson & Emmorey, 1997). If so, then STM capacity is, at its root, governed by a general processing limitation that is not affected by language modality. However, this claim has never been adequately tested.

If articulation time does not fully account for the sign-speech difference in STM, then other differences between sign and speech may be important. In particular, because vision and audition have strikingly different information-processing characteristics, the sign-speech difference could be due to perceptually based coding. If so, then the principles governing STM are locally determined and cannot be generalized across language modalities.

Recently Boutla, Supalla, Newport, and Bavelier (2004) addressed this question using stimuli that are articulated very rapidly in ASL. The digits 1 through 9 and the letters of the fingerspelling alphabet in ASL are produced with the fingers of one hand without large-scale movement, and therefore can be produced very quickly. However, the hand shapes for the digits 1 through 9 in ASL are similar, and formational similarity reduces STM (Klima & Bellugi, 1979; Wilson & Emmorey, 1997). Therefore, Boutla et al. used the Digit Span task from the Wechsler Adult Intelligence Scale (WAIS), but substituted ASL letters for digits. Signers were tested with ASL letters, and speakers with spoken English digits. Span was still longer for English than ASL. The authors concluded that STM for spoken language benefits from auditory-based representations and does not reflect a standard capacity of STM that applies across domains.

However, that study compared signed letters with spoken digits, and recent evidence suggests that digits have a special status in STM, yielding better performance than otherwise matched lexical items (Jeffries, Patterson, Jones, Bateman, & Ralph, 2004). Thus, digits and letters may not be comparable categories for testing STM. A better option, then, would be to compare ASL letters with English letters.

We report here the results of three experiments. The first two verified that digits yield better STM than letters. The third experiment returned to the original question: whether superiority of spoken language in STM persists when articulatory duration is controlled. We used the WAIS Digit Span task (Wechsler, 1955), in which sequences of items are presented at a rate of one per second and must be repeated by the participant in the correct order. Sequences increase in length, with two sequences of each length, and the test concludes when the participant fails on both sequences of a particular length. One point is awarded for every correct sequence.

EXPERIMENTS 1 AND 2

Nine letters (*Y*, *Q*, *R*, *O*, *D*, *L*, *W*, *J*, and *V*) were chosen to match the digits 1 through 9 in stimulus duration and phonological similarity across items within the set, when spoken in English. Thus, for example, the digits 5 and 9 share a vowel sound, so the letters *D* and *V* were chosen because they share a vowel sound, and the multisyllabic letter *W* was chosen to correspond to the multisyllabic number 7. For the letter condition, the WAIS digits were replaced by these letters.

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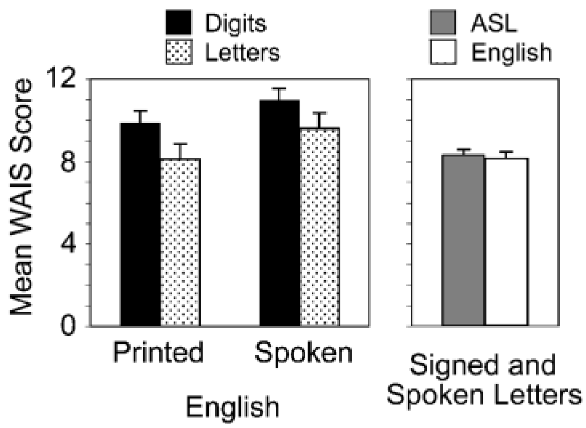

Fig. 1. Short-term memory performance (mean Wechsler Adult Intelligence Scale, WAIS, score) for printed English digits versus letters (Experiment 1), spoken English digits versus letters (Experiment 2), and spoken English letters versus signed American Sign Language (ASL) letters (Experiment 3).

Experiment 1 used printed stimuli. Participants were 8 native English speakers. Resulting mean WAIS scores were 9.9 for digits and 8.1 for letters, $t(7) = 3.13$, $p_{\mathrm{rep}} = .94$, $d = 0.66$ (see Fig. 1). Experiment 2 used video clips of the sequences spoken aloud. Participants were 8 native English speakers. Mean scores were 11.0 for digits and 9.6 for letters, $t(7) = 2.76$, $p_{\mathrm{rep}} = .96$, $d = 0.97$ (see Fig. 1).

Thus, whether stimuli are presented in print or aloud, digits yield higher STM spans than letters do. This might be because people have greater experience rehearsing numbers, because digits constitute a smaller category, or because numbers induce a representation of magnitude (Knops, Nuerk, Fimm, Vohn, & Willmes, 2006). In any case, stimulus category (digit vs. nondigit) must be controlled along with other factors when testing STM capacity.

EXPERIMENT 3

The letters used in Experiment 3 were *B*, *F*, *H*, *K*, *L*, *R*, *S*, *V*, and *X*. In this case, the goal was to use the same letters for the ASL and English stimuli while at the same time to match the two sets for articulatory duration and phonological similarity within the set. Thus, the letters *J* and *Z* were not used because of their longer articulation time in ASL, and the set was chosen to be as phonologically diverse as possible in both languages. Stimuli were video clips of a model fluent in both ASL and English, signing or speaking each sequence. Participants were 12 Deaf ASL signers (11 from Deaf signing families, 1 exposed to ASL beginning in preschool), and 16 hearing English speakers (14 from monolingual homes, 2 from bilingual homes).

Mean scores were 8.3 for ASL and 8.1 for English, $t(26) = 0.49$, $p_{\mathrm{rep}} = .62$, $d = 0.18$ (see Fig. 1). Thus, in contrast to Boutla et al. (2004), we found no difference in span between ASL and English. Boutla et al. used an alternate scoring method, in which the score is simply the length of the longest correct sequence. Using this method, the mean scores in Experiment 3 were 5.3 for ASL and 5.6 for English, $t(26) = 0.96$, $p_{\mathrm{rep}} = .74$, $d = 0.38$, again showing no difference in span.

DISCUSSION

We conclude that STM for ASL and STM for English do not in fact differ in underlying capacity. Instead, the usually observed difference in span is due to other factors known to affect STM, most notably articulation time, which differs substantially between ASL and English for most lexical items. This conclusion has important implications for models of STM. In particular, it implies that the time required to articulate the to-be-remembered materials is a universal constraint on STM capacity, regardless of sensory modality.

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