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A Comparison between Children's and Adults' Ability to Detect Conceptual Information Conveyed through Representational Gestures

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The present study compares children's and adults' ability to detect information that is conveyed through representational hand gestures. Eighteen children (M = 10 years, 1 month) and 18 college undergraduates watched videotaped stimuli of children verbally and gesturally explaining their reasoning in a problem-solving situation. A recall procedure was used to assess whether children and adults could detect information conveyed in the stimulus children's gesture and speech. Results showed that children and adults recalled information that was conveyed through representational gestures. In addition, "mismatching" gesture negatively affected the precision of speech recall for adults. However, this negative effect on speech recall was absent for children.

INTRODUCTION

When people communicate, they do more than talk. People often convey information through nonverbal behaviors in addition to verbal behaviors. Moreover, information conveyed through nonverbal behaviors often has a powerful impact on a listener's interpretation of the accompanying spoken information. For example, consider what effect a negative tone of voice and sad facial expression has on the utterance, "I'm having a great day." Or consider how a hand gesture portraying the shooting of a basketball can impact the interpretation of the utterance, "Do you want to go to the gym later?" In the first example, the person's tone of voice and facial expression greatly change the meaning of the spoken utterance, turning it into a sarcastic expression suggesting that the day was, in fact, not great. In this way, nonverbal behaviors can add important *affective* information to speech. In the second example, the shooting gesture provides a clearer and more complete picture of what the speaker is asking—he wants to know if his friend wants to go play basketball later. In this way, certain nonverbal behaviors can add substantive *representational* information to speech. We briefly review research that has investigated expression of these two types of nonverbal information.

Most of the work that has investigated the production of nonverbal behaviors has looked at the expression of nonverbal affective information. These studies have demonstrated that adults and children produce nonverbal behaviors to convey several types of affective information (such as information about emotional states, preferences, and attitudes) through various types of behaviors (e.g., facial expressions and tone of voice) (Buck, 1975; Ekman, 1979; Mehrabian & Ferris, 1967). Moreover, these behaviors often have varying relations to the accompanying speech. For example, behaviors such as facial expressions and tone of voice can convey information that is redundant with speech, thus reinforcing the spoken message. However, sometimes these nonverbal behaviors convey information different from that conveyed in speech (as in the earlier example involving sarcasm), suggesting that people can simultaneously send contrasting pieces of information through verbal and nonverbal channels.

More recently, research has demonstrated that people can express not just general, affective information through nonverbal behaviors: they can also convey substantive, representational information. For example, McNeill (1992) has shown that the spontaneous hand gestures that accompany verbal expressions of knowledge can reflect imagistic information (e.g., object attributes, actions, and spatial relations) which distinguishes them from gestures that do not convey imagistic information like deictics or "beats" (small, rhythmic hand movements that have no discernible representational meaning). These representational gestures have been referred to in a variety of ways such as "iconics" (McNeill, 1992), physiographic gesture (Efron, 1941), kineto-graphic gesture (Freedman & Hoffman, 1967), and pictographs or illustrators (Ekman & Friesen, 1977). Moreover, he argues that gesture often provides additional information about a speaker's thoughts that cannot be found in speech, as was the case earlier in the basketball example. In that example, gesture provided information beyond that conveyed in speech and may have ultimately sent a message that may have allowed others to better understand what the speaker (gesturer) specifically had in mind while communicating.

Although most of McNeill's work has looked at adults' gestures, other researchers have specifically focused on children's gestures. For example, in a study investigating the role of gesture in children's explanations of Piagetian conservation problems to adults, Church and Goldin-Meadow (1986) discovered that children frequently produced these representational gestures during their spoken explanations of their solutions to the conservation problems. These gestures, like the spoken explanations, conveyed information about the conservation task attributes (e.g., gestures represented width information, height information, and length information) as well as action information (e.g., gestures represented the pouring of water, the moving of sticks and the spreading out of checkers; see Church & Goldin-Meadow, 1986, for a description of these gesture/speech combinations). Church and Goldin-Meadow showed that when a child produced gestures that mismatched speech in information conveyed in a conservation task, that child was "ready" to benefit from instruction in conservation and, thus, in a transitional knowledge state.

Because nonverbal behaviors frequently add important information to speech during communication, it makes sense to ask whether other people can detect this information. Most of the research on this topic has looked at adults' and children's ability to pick up nonverbal affective information from other people. For example, it has long been known that adults are very good at gleaning affective information from such behaviors as facial expression and tone of voice (Davitz, 1964; Marsden, 1965). Moreover, there have been many studies showing that adults use nonverbal affective information to make sense of discrepant messages, that is, messages that convey contrasting verbal and nonverbal information (Buck, 1975; Bugental, Kaswan, & Love, 1970; Mehrabian & Wiener, 1967; Solomon & Ali, 1972). The aggregate message of these studies is that adults use nonverbal information in conjunction with verbal information to make sense out of multimodal expressions.

Studies have also looked at children's ability to detect nonverbal affective information. For example, Camras et al. (1990) showed that even 3-year-old children can "read" emotional information from different facial expressions of people. Other studies have examined children's response to discrepant messages (where speech is accompanied by contrasting *affective* nonverbal behavior such as tone of voice and facial expression). These studies have demonstrated that during middle childhood, children are capable of detecting this nonverbal communication (Bugental et al., 1970; Reilly & Muzekari, 1979; Solomon & Ali, 1972). However, these studies point out that for children, this contrasting affective information was less likely to influence their interpretation of the speech. For example, Bugental et al. (1970) showed that when children were presented with someone saying something negative with positive affect, children ignored the affective information and interpreted the utterance literally. These results suggest that although detection of nonverbal behavior becomes apparent during middle childhood, children still show a difficulty in integrating nonverbal behavior that is discrepant from speech. One goal of this study was to explore whether this pattern of nonverbal construal could be generalized from the domain of affective nonverbal behavior to the domain of representational nonverbal behavior.

Only recently have researchers looked at detection of nonverbal *representational* information. For example, in a study looking at adults' detection of children's gestures, Goldin-Meadow, Wein, and Chang (1992) reported that adults detected specific information from children's speech and gestures when observing videotapes of children participating in a series of Piagetian conservation tasks. Focusing on children's detection abilities, Thompson and Massaro (1986, 1994) showed that 3-, 5-, and 9-year-olds were capable of picking up information conveyed through simple gestures (i.e., deictics). Also focusing on children's detection, Kelly and Church (1997) did a study similar to the Goldin-Meadow et al. study to see if 7-year-olds could pick up information conveyed through representational gestures. They showed children the same stimulus videotapes that were used in the Goldin-Meadow et al. study and found that children, like adults, were capable of detecting information conveyed through representational gestures. However, their data suggest some possible differences between children's and adults' detection abilities. In particular, although Goldin-Meadow et al. found that gesture affected the precision of adults' recall of spoken information (i.e., matching gesture augmented recall of speech and mismatching gesture detracted from recall), Kelly and Church failed to find these same effects. However, these two studies differed in the task demands of their participants. The Kelly and Church study required children to perform two detection tasks, whereas the Goldin-Meadow et al. study required adults to perform only one. Thus, children's inability to integrate gestural information with speech may have been due to the greater demands of the procedure rather than simply to a developmental limitation.

The present study measured children's and adults' detection of gesture and speech information using the same procedures. Specifically, we examined children's and adults' ability to detect information that is conveyed solely through gesture. This is important because even though studies have compared children's and adults' ability to detect nonverbal *affective* information, no comparisons have been made between their abilities to detect nonverbal *representational* information. Second, we will examine the extent to which: (1) gestures that convey the same information as speech augment recall of spoken information and/or (2) gestures that convey different information than speech detract from recall of spoken information. Based on research on cognitive differences (e.g., working memory, attention) between children and adults (Bisanz, Danner, & Resnick, 1979; Kail, 1990) and based on research showing differences between children's and adults' ability to integrate verbal and nonverbal affective information (Bugental et al., 1970; Reilly & Muzekari, 1979; Solomon & Ali, 1972), we hypothesized that gesture may not have the same impact on speech for children and adults.

METHOD

Participants

Eighteen fourth-grade, full conserving children ($M = 10$ years, 1 month) and 18 college undergraduates participated in the present study. We used 9- to 10-year-old children for two reasons. First, because there is literature comparing 9- and 10-year-olds' and adults' ability to pick up nonverbal affective information, we wanted to make this comparison in the realm of nonverbal representational information. Second, because our child participants were to view stimulus tapes of other children performing Piagetian conservation tasks, we wanted to assure that our participants had a solid understanding of the conservation concept so that any differences between children and adults would not be attributed to differences in conservation understanding. Whereas some third-grade children (7–8 years old) may not have acquired a solid understanding of conservation, fourth graders (9- to 10-year-olds) clearly have (Piaget, 1967).

Procedure

Participants were individually told that they were going to watch videotapes of children explaining their answers to problems. Next, the experimenter familiarized participants with the types of problems that the children on the tape would be solving. To ensure that participants understood the recall question, they first participated in two practice trials. In these trials, the participant was asked the question, "How do you think the child on the tape explained his (her) answer?" after viewing a practice stimulus. If a participant did not understand the procedure after the two practice trials, he or she was excluded from the study. One potential child participant was excluded for this reason. After participants demonstrated understanding of the procedure, they were presented with the stimulus tape. Participants viewed each vignette twice (to ensure that they had clearly seen and heard the stimulus child) and were then posed the recall question. This question was posed after the presentation of each vignette until all nine had been viewed. After the participant's recollection, the experimenter responded with a scripted set of comments to control for selective reinforcement of participant's recollections. First, the experimenter asked, "Is there anything else?" and then said, "OK, let's move on to the next one." This entire procedure was videotaped. Following this task, children were given a set of six Piagetian conservation tasks (tasks identical to those viewed on the stimulus tape) to make sure that they were all full conservers (see Kelly & Church, 1997, and Church & Goldin-Meadow, 1986, for a full description of the conservation tasks). The entire procedure lasted approximately 20 min.

The Stimulus Tape

The stimulus tape consisted of nine 7- to 8-year-old children solving and explaining their answers to questions about conservation problems. The vignettes were taken from videotapes collected in prior studies of children's spontaneous spoken and gestured responses to Piagetian conservation tasks. Three of the problems tapped conservation of liquid quantity, three tapped conservation of length, and three tapped conservation of number. All of the children on the stimulus tape judged the transformed quantities to be different and produced verbal explanations that were nonconserving.

To determine gesture's effect on the accompanying speech and whether the participants were able to detect information conveyed solely in gesture, the stimulus tape was constructed in the following way: In a third of the stimulus vignettes, no gestures accompanied speech (no-gesture condition); in a third of the vignettes, gesture provided the same information as speech (gesture-speech match condition); and in the final third, gesture provided different information from speech (gesture-speech mismatch condition). Each of the three conditions contained all three types of tasks (liquid, length, and number tasks). Take the liquid task as an example. In the no-gesture condition, the child justified her nonconserving judgment by focusing on the different heights of the two containers in speech, "Because one was tall and one was short," and produced no gestures along with her speech. In the gesture-speech match condition, the child expressed height information through her speech and simultaneously produced gestures that also focused on the different heights of the containers: A flat hand was placed over the top of the tall, thin container (indicating "tall" glass) when the child said "tall" and then placed over the top of the short, fat container (indicating "short" dish) when the child said "short" (Church & Goldin-Meadow, 1986). Finally, in the gesture-speech mismatch condition, the child also expressed height information through her speech but simultaneously produced gestures that focused on the different widths of the containers: A small C-shaped hand was held at the width of the tall, thin container (indicating thin container) when the child said "tall," and then a large C-shaped hand was held at the width of the short, fat container (indicating wide dish) when the child said "short."

Note that in the preceding examples, the explanation conveyed through speech was identical in all three conditions. To ensure that the speech was the same across all three conditions, we conducted a control study in which we presented only the audio portion of the stimulus tape to 17 additional individuals. We found that the verbal information was treated equally across all three conditions. All nine stimuli were grouped in this fashion, forming three groups of vignettes (of three each). In each group, the speech always conveyed the same explanation. The only thing that distinguished the three types of stimuli was the information conveyed through gesture. This design allowed us to investigate whether adults and children could detect information uniquely expressed through gesture and also whether gesture affected the detection of the speech it accompanied. Two stimulus tapes were created, each containing a different randomized order of the same nine vignettes. The order that a participant viewed was randomly determined by the flip of a coin.

RESULTS

In this section, the results from the recall task are presented. We focus on two aspects: (1) adults' and children's ability to detect information conveyed through gesture and (2) adults' and children's ability to detect information conveyed through speech.

Detection of Information Conveyed through Gesture

The first set of analyses looked at participants' ability to pick up information conveyed in gesture. This was measured by looking at participants' memory for the information that was conveyed by the stimulus children. In particular, we looked for recollections of stimuli in which participants conveyed additional information that was not conveyed in the stimulus children's spoken explanations.[1] We classified these Additions into two types: "Traceable Additions" and "Untraceable Additions."

The majority of Additions produced by participants conveyed the precise information that was expressed in the stimulus children's mismatching gestures. This particular type of Addition was called a "Traceable Addition" because the information contained in it could be directly traced back to the information conveyed in a mismatching gesture. For example, consider the mismatching child in the stimulus tape who justified her nonconserving judgment by verbally focusing on the different heights of the two containers while producing gestures that focused on the width of the containers. An example of a Traceable Addition would be if a participant said, "The child thinks that one is thin and one is wide." The participant's mention of width could be *traced* back to the mismatching child's gestures (which focused on the width of the container).

In this example, however, it could have been that the Traceable Addition was produced because width information was a salient dimension in this particular task rather than as a function of the mismatching gestures conveyed in the stimulus tape. If this were the case, one would expect the frequency of (what we are calling) Traceable Additions to be about the same for all three types of stimuli (mismatching, matching, and no-gesture). There were 54 Traceable Additions possible for each of the three conditions. However, whereas 13 of the adults' Additions to mismatching stimuli were Traceable Additions, only five of the adults' Additions to matching stimuli and four Additions to no-gesture stimuli were Traceable Additions, $F(2, 51) = 3.65$, $p < .05$ (see Figure 1). The ANOVA was performed on the average number of Additions

1. Note that even though participants often gestured when they produced recollections, we only focused on the speech portion of the response in the present article.

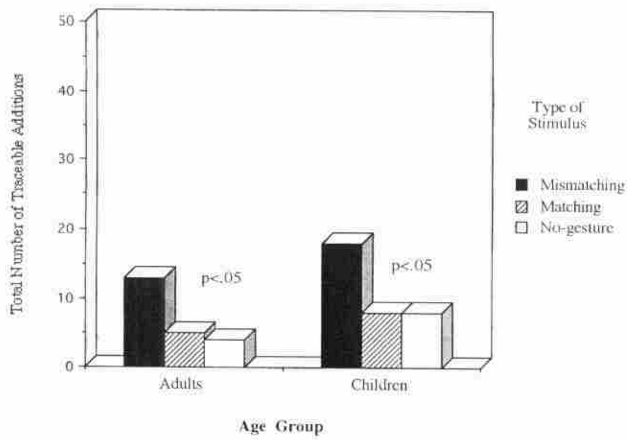

Figure 1 Adults' and children's Traceable Additions to mismatching, matching, and no gesture stimuli.

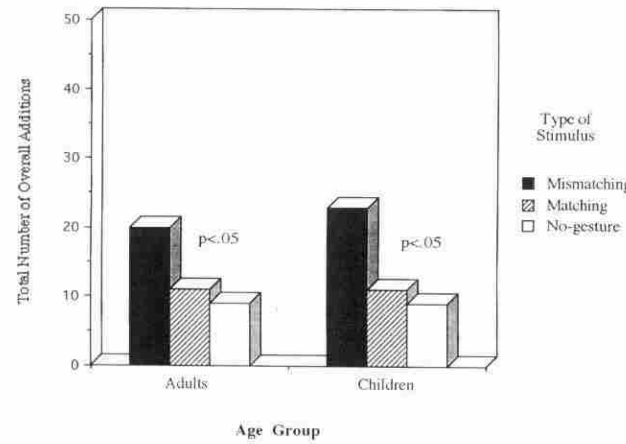

Figure 2 Adults' and children's Overall Additions to mismatching, matching, and no gesture stimuli.

per participant, but the text and graph present raw numbers because they demonstrate the phenomenon more clearly. For children, a similar pattern emerged. Whereas 18 of the children's Additions to mismatching stimuli were Traceable Additions, only eight Additions to matching stimuli and eight Additions to no-gesture stimuli were Traceable Additions, $F(2, 51) = 4.12$, $p < .05$ (see Figure 1).

Most of the additions produced by participants were Traceable Additions. However, participants occasionally produced Additions that contained information that could not be traced directly back to information that was conveyed in the stimulus children's mismatching gestures. These were called "Untraceable Additions." For example, suppose a participant viewed the above mismatching vignette in which the stimulus child compared height in speech but width in gesture. A recollection would be coded as an Untraceable Addition to the verbal explanation if a participant said, "She thinks they are different because the glass was poured into a new container." This response is an Untraceable Addition because the participant produced information about the transformation of the quantity even though this information had not been expressed in the spoken or gestured portion of the stimulus child's explanation. Untraceable Additions to mismatching stimuli were an indirect measure of gesture detection because they suggested that something more than speech had been processed in the mismatching stimuli. In other words, because gesture was the only thing that was different about mismatching stimuli, more Additions to mismatching stimuli suggested that gesture had been processed on some level.

As an overall, gross measure of gesture detection, Traceable *and* Untraceable Additions were combined into a single analysis. Specifically, the overall number of Additions (Traceable and Untraceable) produced in response to mismatching stimuli was compared to the overall number of Additions to matching and no gesture stimuli. Adults produced 20 overall Additions to mismatching stimuli, 11 to matching stimuli, and 9 to no-gesture stimuli, $F(2, 51) = 3.82$, $p < .05$ (see Figure 2).[2] Next, the number of overall Additions that the children produced was calculated and analyzed. Children produced 23 overall Additions to mismatching stimuli, 11 to matching stimuli, and 9 to no-gesture stimuli, $F(2, 51) = 4.46$, $p < .05$ (see Figure 2).

Detection of Information Conveyed through Speech

The above analyses suggest that gesture does influence detection of spoken information. Not only did participants add more when presented with mismatching stimuli, but they often incorporated specific gestural information into their recall of what was said by the stimulus children. The next analysis was a more subtle look at *how* detection of gesture influenced how precisely the spoken information had been recalled. There could be three possible influences: (1) Matching gestures could augment memory for speech because of the redundancy of information in the matching gestures, (2) mismatching gestures could detract from memory for speech because the contrasting information contained in the mis-

2. It is important to note that gesture detection did not get better with more exposure to the stimuli. This suggests that participants naturally pay attention to gesture and were not "learning" to pay attention to it over the course of the experiment.

matching gestures could confuse memory for speech, and (3) gesture could have no effect on how well spoken information was remembered.

To measure how well participants remembered spoken information, the number of times that participants precisely repeated information that was conveyed through speech was calculated. A recollection was coded as a Repetition if that recollection contained the same information as that conveyed in the stimulus child's spoken explanation. For example, suppose a participant viewed a vignette in which the stimulus child explained that the two containers had different amounts because one was tall and the other was short. A recollection was coded as a Repetition if the participant said the following, "The girl thinks they're different because one was tall and the other was short." The participant simply repeated what was said. The recollection would have also been coded as a Repetition if the participant said the following, "She thinks they're different because one was tall *and thin* and the other was short *and wide*." Note that in this second example, the response counts as both a Repetition and an Addition because it provides information that the child actually said and also adds new information. Thus, the Repetition and Addition codes were not mutually exclusive.

The total number of Repetitions produced by adults for each of the three types of stimuli was calculated and analyzed (there were 54 Repetitions possible for each). Adults produced 40 Repetitions to mismatching stimuli, 49 to matching stimuli, and 50 to no-gesture stimuli, $F(2, 51) = 4.14, p < .05$ (see Figure 3). Student's planned contrast analyses indicated that adults produced the same number of Repetitions for matching and no-gesture stimuli, $t(17) = .6$; *ns*, but

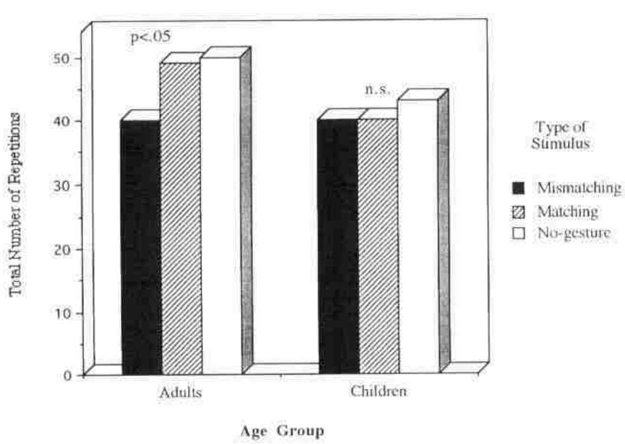

Figure 3 **Adults' and children's Repetitions to mismatching, matching, and no gesture stimuli.**

produced significantly fewer Repetitions to mismatching stimuli than to matching stimuli, $t(17) = 2.14$, $p < .05$, and no-gesture stimuli, $t(17) = 2.74$, $p < .01$. These results suggest that matching gestures did not augment recall of spoken information, whereas mismatching gestures detracted from adults' recall of spoken information.

Next, the total number of Repetitions produced by children for each of the three types of stimuli was calculated and analyzed. Children produced 40 Repetitions to mismatching stimuli, 40 to matching stimuli, and 43 to no-gesture stimuli, $F(2, 51) = .43$, *ns* (see Figure 3). Therefore, it appears that matching and mismatching gestures did not augment or detract from children's memory for speech.

Detection of Information Conveyed through Speech and Gesture

The final analysis looked at how often people picked up both speech *and* gesture information. To do this, we tallied the number of times that people detected gesture, and given this detection, we calculated the percentage of times that people also detected speech information. On average, when adults detected gesture, they also detected speech 93% of the time. Whereas when children detected gesture, they detected speech 60% of the time, $t(14) = 1.9$, $p < .05$. This result suggests that adults may be better than children at simultaneously paying attention to multiple pieces of information during communication.

DISCUSSION

The preceding results provide some preliminary answers to the two questions put forth at the beginning of the article: (1) Adults and children are capable of detecting information conveyed through speech and gesture, and (2) there appears to be a developmental difference in how gestures influence memory for spoken information.

Developmental Implications

There have been many studies that have shown that children and adults are good at picking up *affective* information conveyed through nonverbal behaviors (Buck, 1975; Bugental et al., 1970; Camras et al., 1990; Davitz, 1964; Marsden, 1965; Mehrabian & Wiener, 1967; Solomon & Ali, 1972). Moreover, researchers have argued that detection of this nonverbal affective information actually influences interactions among and between children and adults (for a theoretical account, see Crick & Dodge, 1994). The present experiment complements these studies by showing that children and adults are also capable of picking up *representational* information conveyed through hand gestures. This is important because it is likely that the detection of nonverbal representational information influences communicative interactions just as detection of nonverbal affective information does. This finding is especially pertinent to communicative interactions in educational contexts. For example, studies have shown that children (Church & Ayman-Nolley, 1995) and adults (Granott, 1993) produce many gestures while teaching and learning new concepts. Given that children and adults pick up information conveyed through gestures, it is important to consider the impact that gesture may have on the cognitive and social processes involved in educational interactions.

What is particularly interesting about the gesture detection findings is that participants naturally included gestured information into their recollections of the stimulus children's explanations without any special instructions to pay attention to nonverbal behaviors. In addition, when asked about their recollections in an exit interview, participants almost always reported that their recollections were based on information that they had heard in speech (and not seen in gesture). These results run counter to claims that gesture does not play a significant role in communication (Krauss, Morrel-Samuels, & Colasante, 1991). In addition, these findings seem to contradict modular theories of speech and gesture processing (Levelt, 1989). Although Levelt's theory focuses on language production, his model implies that speech and gesture are also perceived in a modular fashion. Based on this, it is likely that his model would predict that speech and gesture do not influence one another during construal. In contrast, our results support the claim that gesture and speech make up an integrated system (McNeill, 1992). This claim is based on data that show that when adults are presented with contrasting speech and gestural information, they not only integrate gestured information into their memory for speech but they are also usually inaccurate in identifying the source of their memories. These data mirror the results from the present experiment. Below, we explore in more detail the relation between speech and gesture for children and adults.

In general, the results show a trend that adults are better at precisely recalling information conveyed through speech (as indexed by the greater overall number of Repetitions). This is not surprising. Adults have a better and more precise memory for speech than children (Ceci & Bruck, 1993; Huttenlocher & Burke, 1976). However, the adults in our study were not *always* better than children in their ability to remember spoken information. When adults were presented with mismatching stimuli, their recall of the spoken information suffered. This makes sense when one considers the nature of the mismatching stimuli. Mismatches convey multiple pieces of nonredundant information through speech and gesture, perhaps adding a "load" to the adults' processing capacity (for more on "cognitive load," see Shiffrin & Schneider, 1977). Indeed, research has shown that gesture-speech mismatches such as the ones used in our stimuli have been shown to tax cognitive effort in a word recall task (Goldin-Meadow, Nusbaum, Garber, & Church, 1993). Finally, it is interesting to note that matching gestures did not augment memory for spoken information (cf. Thompson, 1995). We believe that this may be due to the fact that the stimuli in our experiment were all very short and simple, perhaps causing adults to perform at ceiling levels for the no-gesture and matching gesture conditions.

Children, on the other hand, did not show a differential effect of recall of speech across *any* of the three experimental conditions. This finding is particularly interesting considering that children detected gesture at the same level as adults. We offer several possible explanations for this pattern of results. On one hand, it is possible that mismatching gestures really *did influence* children's memory for speech, but our dependent measure (number of Repetitions) was not sensitive enough to pick up the differences. A related possibility is that children's overall processing limitations (Bisanz et al., 1979; Kail, 1990) overrode any detrimental effect that the mismatching gestures had on precise recall for speech. That is, perhaps children's memory for speech was already as bad as it was going to get and adding an extra piece of information in a mismatching gesture was not going to make it any worse.

On the other hand, it is possible that mismatching gestures *did not influence* children's precise memory for speech. If this were the case, it would suggest that children and adults process multiple pieces of nonredundant information differently during communication. For example, perhaps adults are more likely to integrate speech and gesture into a single unified representation (the McNeill model), resulting in a decrease in the precise memory for speech. In contrast, children may treat speech and gesture more separately from one another (the Levelt model), and thus, their precise memory for speech would not be negatively influenced. Indeed, children were not as likely as adults to combine speech and gesture into their recollections (60% versus 93%). This suggests that children may still be developing their ability to integrate multiple pieces of information during communication. This explanation is supported by research which examines developmental changes in the processing of mismatching emotional messages (Bugental et al., 1970; Mehrabian & Wiener, 1967; Reilly & Muzekari, 1979; Solomon & Ali, 1972). Future studies need to more specifically address how children and adults differ in their abilities to integrate verbal and gestural information.

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