Research Report

Language and Action Control

The Acquisition of Action Goals in Early Childhood

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ABSTRACT—*This study examined the role of verbal labeling in 4-year-old children's acquisition of action-effect learning. The acquisition of action-effect associations was tested by having children first perform a two-choice key-pressing task in which each key press was followed by an effect (i.e., a particular sound) and then respond to the previously perceived effects under either consistent or inconsistent key-sound mappings. During acquisition, the children overtly described the actions, the effects, both the actions and the effects, or, in a control condition, something irrelevant to the actions and effects. Action-effect learning was reliable only if the description related actions to effects, even though some evidence of learning was also obtained in the control condition. In contrast, learning was prevented if only the actions or only the effects were described. The results suggest that verbal labeling plays an important role in integrating and isolating event representations.*

Vygotsky (1934/1962) was probably one of the first to assume a central role of language in the emergence of voluntary action in humans. In particular, he claimed that the dynamic interplay between language and action regulation undergoes a transition in early development: In the young child, action comes first. Imagine a child painting something. He or she is likely to first finish the picture and then say what he or she has painted. In the next phase, action and speech go together, so that the child will talk while painting an object. In the final stage, speech commonly precedes action: The older child will say what he or she intends to paint before actually starting to paint. Apparently, by this point, speech has taken on a self-regulatory function in specifying the action goal.

Considering this example, one can envision at least two functions of language in the development of action control. First, children and adults seem to use speech for action planning, that is, for representing and maintaining action plans and if-then rules (e.g., Baddeley, Chincotta, & Adlam, 2001; Emerson & Miyake, 2003; Goschke, 2000; Kirkham, Cruess, & Diamond, 2003; Kray, Eber, & Lindenberger, 2004; Luria, 1959, 1961, 1969; Vygotsky, 1934/1962; Zelazo, 1999). A second, probably earlier, function of language in the development of action control may be that verbalizing and labeling an action or its outcome (i.e., effect) is helpful for abstracting, isolating, and generalizing the event. For instance, when verbally describing his or her painting, and the action creating it, a child highlights some but not other features of the action and the effects and, hence, characterizes them in an actor- and context-specific fashion. As Zelazo (1999) and Hermer-Vazquez, Spelke, and Katsnelson (1999) have considered, language may be well suited to integrate relationships between events; that is, language may also facilitate the binding of actions to outcomes (action-effect learning). In more general terms, as language emerges in the course of ontogenetic development, it may increasingly serve to separate or flexibly combine representations of other more domain-specific systems. In the present study, we investigated whether and how children's integration of actions and effects is facilitated or hampered by having the children verbally describe their own actions in ways that either connect or separate actions and effects.

According to ideomotor approaches to action control (e.g., Greenwald, 1970; Hommel, Müsseler, Aschersleben, & Prinz, 2001; James, 1890), action-effect learning creates the cognitive basis for voluntary action. The idea is that performing a movement induces more or less automatically a bidirectional association between the motor pattern that produces the movement (m) and the sensory effects (e) the movement produces. The acquisition of action-effect associations has been demonstrated in young adults (for reviews, see Hommel, 2004a and 2004b) and, most important for our purposes, in young children. In a recent series of experiments (Eenshuistra, Weidema, & Hommel, 2004), we investigated age-related changes in the acquisition and use of action-effect associations in 4- and 7-year-old children. In an *acquisition* phase, children freely chose one of two

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key presses (m_1 and m_2) in each trial, and each key press was followed by a particular tone effect ($m_1 \rightarrow e_1$, $m_2 \rightarrow e_2$). In the *test* phase, children responded to the tones by pressing keys, and the assignment of keys to tones was either consistent or inconsistent with the mapping in the acquisition phase. Children with acquisition-consistent mappings ($e_1 \rightarrow m_1$, $e_2 \rightarrow m_2$) performed better than children with acquisition-inconsistent mappings ($e_1 \rightarrow m_2$, $e_2 \rightarrow m_1$); that is, a mapping-consistency effect was obtained.

Interestingly, the two main measures, reaction times (RTs) and error rates, were differentially sensitive to age and practice (Eenshuistra et al., 2004). RTs showed similarly pronounced mapping benefits for the two age groups when the action effects were also present in the test phase (cf. Experiments 3 and 4). Given that the mapping benefit for RTs was also obtained when the children had no previous practice (no acquisition phase in Experiment 4), this benefit seems to reflect some sort of fast adaptation rather than true learning. In contrast, the mapping benefit for error rates was obtained only when the children had previous practice (in the acquisition phase) and varied with age: Four-year-olds made substantially more errors under inconsistent- than under consistent-mapping conditions, whereas 7-year-olds showed no mapping benefit. In summary, action-effect learning was indicated by the mapping benefits in the error data, and the younger children were less efficient than the older children in overcoming previously learned action-effect associations in order to maintain and implement a currently relevant set of task rules in the test phase.

In the present study, we investigated whether young children's ability to integrate actions and their perceived effects (as measured by a mapping-consistency effect in a later test phase) is influenced by different kinds of verbal labeling. Specifically, we examined verbal labeling focusing attention to the actions, the effects, or both, as well as verbal labeling that was relevant to neither the actions nor the effects (the control group). If language serves to characterize an action by attracting attention to some of its features at the expense of others, one would expect that describing only the actions or only the effects would work against action-effect integration. Accordingly, we expected less action-effect learning under action and effect labeling than under the control condition. Also, if verbal labels are particularly well suited to create event relations (Hermer-Vazquez et al., 1999; Zelazo, 1999), one would expect that verbalizing the relationships between actions and their effects would facilitate action-effect associations. Accordingly, we expected the most action-effect learning under action-plus-effect labeling.

METHOD

Participants

Participants were one hundred five 4-year-old children recruited from four kindergartens in South Germany. Seven children were unable to perform the tasks, and 2 children did not complete the experiment, leaving a sample of 96 (see Table 1). All children received small presents for participating, and the kindergartens received some money to purchase language games.

Stimuli and Apparatus

A notebook computer was used for data collection and stimulus presentation. The visual stimuli were faces of Ernie and Bert from "Sesame Street" (a television show for young children). The children responded with the left and right keys of an external response box. The auditory stimuli were the sounds of a bell and a trumpet.

Design and Procedure

The experiment was divided into an acquisition phase and a test phase. In the acquisition phase, the children had to press the left or right key as quickly as possible when Ernie appeared. They were told to choose the keys freely but to use them about equally often. For half of the participants, a left key press was followed by a bell sound, and a right key press by a trumpet sound; for the other half, the mapping was reversed. To motivate the young children to complete the acquisition phase, we set up the

TABLE 1
Descriptive Statistics for the Participants

	Verbalization group			
Statistic	Action	Effect	Action plus effect	Control
n	24	24	24	24
Males/females	12/12	11/13	12/12	10/14
Age range (years)	4.0–4.9	4.1–5.0	3.9–4.9	3.9–4.9
Mean age (years)[a]	4.5 (0.3)	4.6 (0.25)	4.5 (0.3)	4.4 (0.3)
Color-naming test[a,b]				
Consistent-mapping group	17.7 (3.57)	18.9 (5.55)	15.4 (5.86)	17.6 (2.84)
Inconsistent-mapping group	17.9 (5.14)	17.4 (3.49)	15.3 (5.37)	17.5 (4.22)

[a]Standard deviations are given in parentheses. [b]Color-naming scores indicate the number of shapes whose colors were correctly named within 45 s.

experiment as a game. The children were told to respond to the appearance of Ernie because he would like to play the game (go trials), but not to respond to Bert because he does not like to play (no-go trials).

The acquisition phase consisted of 144 trials, 96 go- and 48 no-go trials, separated into three blocks. Each acquisition trial started after an intertrial interval of 1.5 s. The go stimulus remained on the screen until a response was made or 7 s had passed. The no-go stimulus remained on the screen for about 2 s.

Verbal labeling was manipulated in four groups. In the *action group*, the children were instructed to name the action (i.e., what they did) after responding. Because 4-year-olds may not have a clear representation of the response labels "left" and "right," the response keys were color tagged (with blue and green stickers), and the children reported in each trial whether they pressed the blue or green key. In the *effect group*, the children had to name the sound (i.e., what they heard) after responding. In the *action-plus-effect group*, the children named both the sound and the action producing it. Children in the *control group* verbalized words (i.e., "pizza" or "spaghetti") that were unrelated to the action and its effect after responding; they were asked to predict what Ernie would like to eat for lunch.

In the test phase, each verbalization group was randomly divided in half; one half received a consistent sound-key mapping, and the other half received an inconsistent sound-key mapping. Under consistent mapping, the children were presented with the previous action effects (sounds) and were instructed to press the key corresponding to the sound on each trial. Under inconsistent mapping, the sound-key assignment was reversed. In this phase, the children were told that Ernie likes to make music, so they should press one key when they heard the sound of a trumpet, and the other key when they heard the sound of a bell. Again, they had to withhold responding when Bert appeared, because "Bert hates music and likes the silence."

The test phase consisted of three blocks of 24 go- and 6 no-go trials. A trial started with an intertrial interval of 1.5 s. The trial procedure was the same as in the acquisition phase, and the sound-key mapping was counterbalanced across subjects. As in the previous study (Eenshuistra et al., 2004), the response keys triggered the corresponding sounds in both the acquisition phase and the test phase to avoid extinction of the action-effect associations (see Elsner & Hommel, 2001).

Matching Procedure

To reduce group differences in the variability of responding, we used the results of a color-naming test to match the children in the four groups according to their verbal speed of responding. In this test, the children saw a sheet of several unfilled shapes (circles, crosses, triangles, squares). A template, presented on the top of the sheet, contained four colored shapes. The children's task was to name as quickly and accurately as possible what color each test shape was on the template. The score was the number of correctly named colors within a time window of 45 s. Subjects with a similar score (± 2) were assigned to different groups (see also Table 1).

TABLE 2
Frequencies and Latencies for Left and Right Key Presses in the Acquisition Phase

	Verbalization group			
Key press	Action	Effect	Action plus effect	Control
	Frequency (%)			
Left	47.08 (7.13)	47.17 (5.51)	48.50 (7.99)	45.54 (6.84)
Right	47.79 (7.08)	47.58 (5.52)	46.63 (7.63)	47.79 (7.50)
	Latency (ms)			
Left	1,441 (366)	1,692 (386)	1,724 (564)	2,005 (530)
Right	1,452 (322)	1,694 (494)	1,713 (571)	2,019 (475)

Note. Standard deviations are given in parentheses.

RESULTS

Verbal Speed

Table 1 shows the mean number of correctly named colors (with standard deviations) for the four verbalization groups. An analysis of variance (ANOVA) including the factors of verbalization group and mapping group revealed that neither the main effects (ps = .16 and .42, respectively) nor the interaction (p = .81) was significant, suggesting that the groups did not differ significantly in their speed of verbal responding.

Acquisition Phase

Left and right key presses were equally distributed in each of the four groups (see Table 2). The latencies for left and right key press were also comparable ($p = .87$), and latencies did not show an interaction between side of key and verbalization group (p = .98). Although the children verbalized only after having made the key-press response, the groups differed significantly in mean latency, $F(3, 88) = 5.96$, $p < .01$, $\eta^2 = .167$. Post hoc comparisons revealed that the control group responded more slowly than the other three groups, $F(1, 88) = 12.86$, $p < .001$, presumably because it was more difficult to verbalize words not associated with the task at hand than to verbalize the actions and effects.

Test Phase

Mean error rates and mean RTs of correct responses were analyzed by means of ANOVAs with the factors of verbalization group and mapping group (see Fig. 1). The error analysis revealed main effects of mapping, $F(1, 88) = 15.06$, $p < .001$, $\eta^2 = .107$, and verbalization, $F(3, 88) = 5.09$, $p < .01$, $\eta^2 = .105$. As the interaction between mapping group and verbalization group was also significant, $F(3, 88) = 4.01$, $p = .01$, $\eta^2 = .08$,

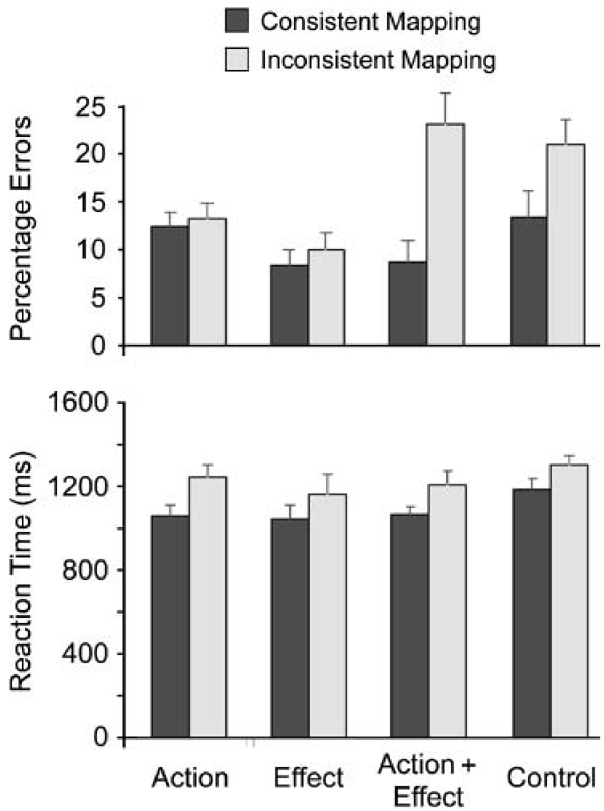

Fig. 1. Percentage errors (top panel) and mean reaction times (bottom panel) as a function of verbalization group (action, effect, action plus effect, or control) and mapping condition (consistent or inconsistent). Error bars refer to standard errors.

a separate analysis was conducted for each of the four verbalization groups and for each of the two mapping groups. The results revealed that the mapping-consistency effect (i.e., more errors under inconsistent than consistent mapping) was reliable when the action and effect were both verbalized, $F(1, 23) = 13.19, p < .01$, but not when only the action ($p = .68$) or only the effect ($p = .50$) was verbalized. Even though the mapping-consistency effect failed to reach significance in the control condition ($p = .06$), the size of the effect in this condition was not statistically different from the size of the effect in the action-plus-effect condition, $p = .53$.

Separate analyses for the two mapping conditions revealed that verbalization affected inconsistent-mapping groups, $F(3, 44) = 6.82, p < .001$, but not consistent-mapping groups, $p = .22$. Post hoc contrasts indicated that in the inconsistent-mapping groups, fewer errors were made under effect labeling and action labeling than under action-plus-effect labeling, $F(1, 44) = 15.14, p < .001$, and $F(1, 44) = 8.55, p < .01$, respectively, and than under control conditions, $F(1, 44) = 10.62, p < .01$, and $F(1, 44) = 5.25, p < .05$, respectively.

In the analysis of latencies, the only reliable effect was a main effect of mapping, $F(1, 88) = 11.25, p < .001, \eta^2 = .106$; responses were faster under consistent than inconsistent mapping. The consistency effect did not interact with the verbalization manipulation ($p = .95$). Moreover, the verbalization groups did not differ significantly in general speed of responding ($p = .12$), which rules out an account of the error pattern in terms of a speed-accuracy trade-off.

DISCUSSION

This study investigated whether the way 4-year-old children describe their own actions has an impact on their integration of actions and novel effects, that is, on their learning of potential future action goals. Indeed, verbalization in the acquisition phase strongly affected action-effect learning as indicated by the mapping-consistency effects in children's error rates in the test phase.

Verbalizing the action or the effect was apparently less demanding than verbalizing irrelevant information (at least as measured in this experiment) but interfered with the acquisition of action-effect relationships. As expected, naming only one member of an action-effect pair attracted attention to that member at the expense of the other. In other words, making some aspect of an event (sequence) more salient than others works against integrating those aspects.

Reliable evidence of action-event learning was obtained only when the effect was described along with the action, that is, when the verbalization related the effect to the action. On the one hand, this result fits quite well with recent observations of Hermer-Vazquez et al. (1999), who found that in spatial memory tasks, verbal shadowing does not impair the use of spatial information but interferes with the integration of different sources of such information. These authors suggested that language, as a uniquely human ability, serves to combine cues from different sources into one coherent representation (cf. Zelazo, 1999). On the other hand, however, we note that the size of the learning effect under action-plus-effect labeling was not statistically different from the size of this effect in the control condition. This result may have been due to a mere power problem that could be overcome with a (substantially) larger sample, but it may also indicate that the selective function of language (i.e., attracting attention to one aspect of an event at the expense of others) is stronger than its integrative function. Thus, although our findings are consistent with the integration hypothesis, more evidence is clearly needed.

Another interesting finding was that the verbalization effects did not affect the RT pattern (cf. Eenshuistra et al., 2004). Presenting effects along with their corresponding actions in the test phase allows for quick learning of contingencies between them. Given our present design, we suggest that the consistency effects in the RT results reflect fast action-effect binding rather than long-term learning. This explains why verbalization in the acquisition phase had no impact on the consistency effect on RTs in the test phase.

To summarize, learning of the effects of novel actions is strongly mediated by the way the actions and their outcomes are verbally described. The present results support the idea that language and self-directed speech are functional in increasing the range of potential action goals that the developing child has at his or her disposal.

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