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The Development of Symbolic Coordination: Representation of Imagined Objects, Executive Function, and Theory of Mind

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Children's developing competence with symbolic representations was assessed in 3 studies. Study 1 examined the hypothesis that the production of imaginary symbolic objects in pantomime requires the simultaneous coordination of the dual representations of a dynamic action and a symbolic object. We explored this coordination of symbolic representations in 3- to 5-year-olds with a modified action pantomime task that employed both a "dynamic action + object" condition and a "hold + object" condition. Consistent with earlier research, production of imaginary symbolic objects rather than body-part-as-objects increased with age, although, even at age 5, children did not perform at adult levels. As hypothesized, children produced fewer body-part-as-object anchors when they were simply asked to hold an object, rather than perform a dynamic action with the object. Study 2 repeated the conditions of Study 1 and examined these conditions in relation to performance on the Dimensional Change Card Sort (DCCS) task. This study replicated the developmental findings of the earlier study and indicated a modest relation between pantomime and the DCCS, which disappeared with age partialled out. Study 3 examined the action pantomime task in relation to the DCCS, false belief, and appearance–reality with 3- to 5-year-olds. Though performance on the DCCS was related to theory of mind, production of imaginary symbolic objects in pantomime was not strongly related to theory of mind or the DCCS. Results are discussed in terms of children's developing reflective competence in coordinating symbolic representations.

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The development of representation remains a fundamental issue in our understanding of cognitive development. These studies explore symbolic representational development from the perspective of an embodied theory of mind (Müller & Overton, 1998a, 1998b; Overton, 2003; Thelen, 2000). Here, both the ability to produce and the ability to interpret symbolic representations are conceptualized as the outcome of a developmental process embedded in the actions of the child.

From an embodied perspective, representational development begins in early infancy with the production of action based representation (Iverson & Thelen, 1999; Langer, 1994; Langer, Gillette, & Arriaga, 2003). Following infancy this development proceeds through childhood first with the emergence of symbolic representation and then to a reflective coordination of symbolic representations, occurring between 3 and 5 years of age (Langer, 1986, 1994). Along with this latter transition comes success in a variety of domains, including the child's theory of mind (Astington & Gopnik, 1988), symbol use (DeLoache & Burns, 1993), and rule use (Zelazo, Frye, & Rapus, 1996). Thus, at this age, children first succeed at symbolic tasks such as the action pantomime task, which is the focus of the present research, (Boyatzis & Watson, 1993; O'Reilly, 1995; Overton & Jackson, 1973), rule use tasks such as the Dimensional Change Card Sort (DCCS; Zelazo et al., 1996), and standard theory of mind tasks such as appearance–reality and false belief (Flavell, 1986; Gopnik & Astington, 1988; Taylor & Flavell, 1984; Wimmer & Perner, 1983; see Wellman, Cross, & Watson, 2001 for a review of false belief). Because of its apparent abruptness, this change has sometimes been described as a kind of "4-year shift" (Gordon & Olson, 1998; Perner & Lang, 2000). Regardless of whether this change is, in fact, abrupt or gradual (Chandler & Sokol, 1999), the novel competencies that appear across several cognitive symbolic tasks at this age, as exemplified in these and other examples, suggest the possibility of a unifying underlying mechanism (Frye, 1999; Perner, Stummer, & Lang, 1999).

The series of studies to be described in this research focus on this 4-year transition and particularly on the child's initial attempts at producing and coordinating symbolic representations. The acquisition of the various cognitive skills relevant to reflective symbolic representation has been studied from several theoretical perspectives, including the development of metarepresentation (Perner, 1991), executive function (Carlson, Moses, & Breton, 2002; Carlson, Moses, & Hix, 1998; Diamond, Kirkham, & Amso, 2002; Hughes, 1998; Russell, 1996, 1999), and intentionality (Gopnik, 1993). In the domain of theory of mind, computational theorists (Fodor, 1992; Leslie, 1987, 2002) have discussed children's competency in terms of the expression of innate systems of knowledge, available only when constraints on the child's computational resources are lifted.

Two recent theories offer a developmental perspective on the acquisition of symbolic representational and reflective symbolic representational skills. Müller and Overton (Müller & Overton, 1998a, 1998b; Müller, Sokol, & Overton, 1998) present a model of development that hypothesizes several levels of representational functioning between infancy and childhood. They argue that representation begins in action and progresses to symbolic and reflective symbolic levels through the mechanism of the child's own action in the world. Following the first few months, during which there is little coordination of action beyond that which is biologically given and hence no representation, the infant begins to coordinate actions at a psychological level of functioning. This level—termed *first-order operations*—constitutes the first action representations. At around 18 months, the child, through the repeated application of first-order operations, begins to demonstrate the ability to coordinate first-order operations (i.e., representations). This coordination of representations—termed *second-order operations*—constitutes a symbolic level of representational functioning. Further development results, at around 4 years of age, in the ability to coordinate symbolic representations (Olson & Cambell, 1993). The coordination of symbolic representations is associated with the ability to reflect upon symbols and it is this skill that is understood to be central to the rapid advance in the 4-year-old's cognition.

This model of levels of representation is similar to the Levels of Consciousness (LOC) model proposed by Zelazo (1999; 2004), which stresses the interdependence of consciousness and action in development and the conceptualization of symbolic representation as a product of action (Zelazo, 2000). Like the Müller and Overton model, the LOC model emphasizes that age-related changes in action control from infancy through the preschool years are dependent on the "level of consciousness" the child attains (Zelazo, 1999; Zelazo, Carter, Reznick, & Frye, 1997; Zelazo & Jacques, 1997). The infant begins at a level of minimal consciousness and attains higher levels of consciousness and representation through action and the process of recursion, which results in the capacity to reflect on these contents of conscious thought.

Although there are some differences between the Müller and Overton and LOC models (e.g., the timing of the levels of recursion), both agree that age 4 years broadly marks the transition from a level of symbolic representation to a level of reflection on symbolic representations. This newly emerging ability is hypothesized to play a critical role in successful performance with tasks including theory of mind, rule use, and pretending with imaginary objects.

COORDINATING SYMBOLIC REPRESENTATIONS

As a first step in exploring the child's developing ability to coordinate and reflect on representations, these studies focus on the child's skill in producing symbolic representations in pretense situations. There is a considerable body of research that examines symbolic development in pretense (see Lillard, 2002, for a recent review). In research on symbol development outside the pretense context, several investigators have identified the differentiation between the symbol and the object, or idea to which the symbol refers, as an important early step in the acquisition of this skill (Huttenlocher & Higgins, 1978; Olson & Cambell, 1993). In particular, DeLoache (1995) proposed that this differentiation results in a "representational insight," which permits the recognition that the symbol-referent relation can be used to solve problems. This constitutes a *dual representation*, a phrase that describes the ability to understand a symbolic object as both an object itself and a symbol that carries meaning in its relation to the referent (Bialystok, 2000; DeLoache, 1987; DeLoache, Miller, & Rosengren, 1997). In a series of studies exploring this development, DeLoache and colleagues have demonstrated that understanding dual representations begins to emerge around 2 ½ to 3 years of age (DeLoache, 1987, 2000; DeLoache et al., 1997). The paradigm employed in this work entails the child watching as a miniature toy is hidden in a scale model of a room. The child is told that a similar but larger toy will be hidden in the corresponding place in a large room and the child is asked to retrieve the object in the large room. DeLoache argued that success in the model-room task requires the symbolic representation of multiple relations. That is, to use the model effectively as a symbol, the child must represent both facets of the model's dual reality; the model as an object itself and the model as a symbol for the large room (DeLoache, 2000). Figure 1 illustrates this form of dual representation.

Although critical to the development of representation generally, the dual representational skills explored by DeLoache, because they do not address the *coordination* of multiple dual representations, are not sufficient to explain the successes that begin to occur around age 4 years in other conceptual tasks such as the action pantomime task. In this latter task, the child pretends to perform actions with absent objects (e.g., pretending to brush teeth with a toothbrush). Research has consistently demonstrated that, like adults with the disorder of ideational or limb apraxia (Goodglass & Kaplan, 1963; Peigneux & van der Linden, 1999; Raymer, Maher, Foundas, Heilman, & Gonzalez Rothi, 1997), children prior to 4 years of age rely almost exclusively on embodied substitutions for the object of action (Boyatzis & Watson, 1993; Elder & Pederson, 1978; O'Reilly, 1995; Overton & Jackson, 1973). That is, instead of producing an imaginary symbolic object for the

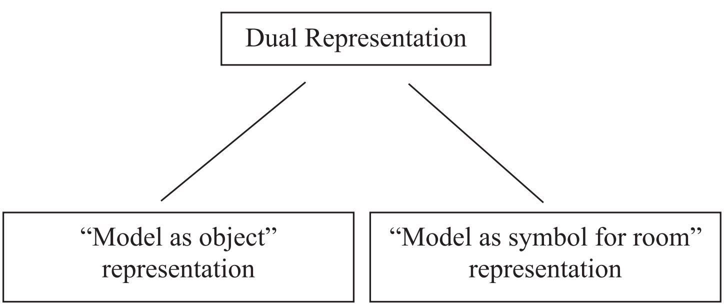

FIGURE 1 Dual representation of the DeLoache model-room task.

actual object, they substitute a body part (e.g., an extended finger to stand for the imaginary toothbrush).

The general literature on children's pretense has demonstrated that pretense in the presence of real objects shows a developmental progression from employing object substitutions that are taxonomically similar to the referent (e.g., using a banana to stand for a telephone), to employing objects that are dissimilar to the referent (Bretherton, 1984; Lillard, 1993). Thus, early in development the child uses taxonomic similarity to "anchor the [symbolic] transformation" (Fein, 1975, p. 295). The findings from prior studies on the action pantomime task suggest that this developmental progression is repeated at a novel level when the physical object of pretense is absent in the pretend situation (Boyatzis & Watson, 1993; Elder & Pederson, 1978; O'Reilly, 1995; Overton & Jackson, 1973). Lacking a "taxonomically similar" physical object to anchor the symbolic representation, the 3- to 4-year-old primarily uses a body-part-as-object (BPO) as an anchor.

A major question is why the child needs an embodied anchor. We believe the answer to this question resides in the inability to *coordinate* symbolic dual representations at a reflective level of symbolic representation. Specifically, we hypothesize that the action pantomime task, as distinguished from the DeLoache situation, which entails a single dual representation, requires the *coordination* of two dual representations. Consider again the pretend action of brushing the teeth with a toothbrush. This dynamic action requires the coordination of the symbolic brushing act with the symbolic object. The representation of action is often ignored in pretense (Leslie, 2002) but because the action of brushing teeth requires the production of a motor schema (O'Reilly, Painter, & Bornstein, 1997), here the dynamic functional nature of the action (i.e., symbolically representing the function of the object) becomes important. Figure 2 shows that both action and object constitute dual representations that must be coordinated. Each separate dual representation of action and object consists of two simple representations. In this situation,

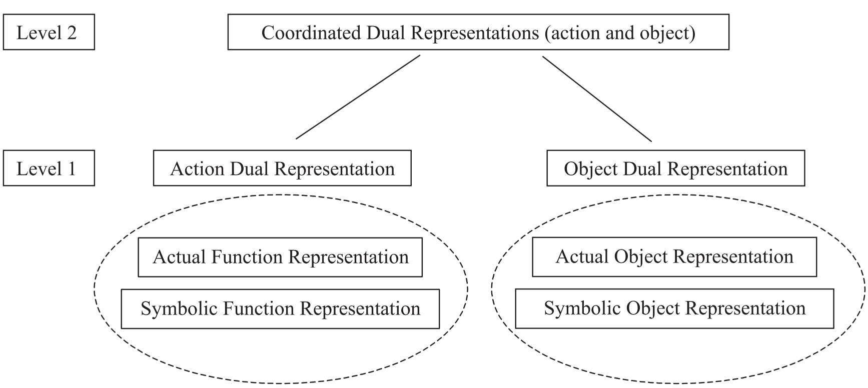

FIGURE 2 Coordinated dual representations.

the action of actually brushing teeth must be coordinated with symbolically brushing the teeth (an action dual representation); actually holding the toothbrush must be coordinated with symbolically holding the toothbrush (an object dual representation). Finally, to perform the pantomime with an imaginary object (IO) substitution, the two dual representations (action and object) must themselves be coordinated. Prior to the reflective level of symbolic representation children have difficulty coordinating two or more dual representations. Through action and the process of recursion discussed by Zelazo (1999, 2000), the ability to coordinate these multiple dual representations emerges (Lillard, 1993) and the child produces imaginary symbolic objects without the simplifying object anchor. This illustrates a qualitative shift with respect to the understanding of the nature of symbols; symbolic substitutions can be created with no tangible anchor in the immediate environment (Sigman & Ungerer, 1981).

In an early study, Overton and Jackson (1973) suggested that this symbolic coordination begins to emerge at around 4 years and continues beyond 8 years of age. Other research (Boyatzis & Watson, 1993; O'Reilly, 1995; Suddendorf, Fletcher-Flinn, & Johnston, 1999) focused on early development in the 3 to 5 year range. Boyatzis and Watson suggested that this skill reaches an asymptote during the preschool years. One focus of this set of studies is to further explore the developmental course of this emerging ability.

A second and more central focus of this research is the exploration of the hypothesis that pantomiming action sequences with symbolic objects does, in fact, require the coordination of two dual representations. As suggested, we begin from the assumption that if a child cannot coordinate the dual representation of the action with the dual representation of the object, then the child employs a simplifying anchor (i.e., BPO) for the object or fails the task completely. If, however, the action representation were to be simplified, effectively simplifying one dual representation, then the object representation should not require the anchor. In this situation, given that the 4-year-old is capable of symbolically representing an object, the child should produce IO substitutions rather than BPO substitutions. In Study 1 of this research, we modified the action pantomime task to include two conditions. The standard condition asks the child to perform a dynamic action with the imaginary object. The second condition simplifies the action by asking the child to merely hold the imaginary object. It is expected that simplifying the action representation by asking children to pretend to hold an object will result in more IO substitutions.

Study 2 is designed to replicate the difference between the action and hold conditions from the first study and to further explore the development of a reflective representational competence. In this study we examine the action pantomime task in relation to the DCCS, a rule use task hypothesized to require the coordination of rule representations in an embedded hierarchy (Zelazo & Frye, 1997). Similarly, in Study 3, we examine the relation between action pantomime, the DCCS, and theory of mind with the expectation that success in these tasks is attributable to a common underlying mechanism, the ability to coordinate representations at a reflective level.

STUDY 1

Method

Participants. Participants were 85 predominately White children from middle-class neighborhoods attending local preschools and day care centers in the Philadelphia area. The participants were divided into three age groups: twenty-six 3-year-olds (*M* age = 43 months: range = 35 to 47 months), thirty-seven 4-year-olds (*M* age = 54 months: range = 48–59 months), and twenty-two 5-year-olds (*M* age = 63 months: range = 60–67 months). Boys and girls were approximately equally represented within each age group. An additional 4 children were removed because they were too old (one 6-year-old) or because they failed the pretest ($n = 3$; see the following section).

General Design. All children completed a pretest and the action pantomime task with both the action and hold conditions.

Pretest. Eight plastic objects were used in the pretest (telephone, hammer, shovel, pencil, cup, comb, saw, and toothbrush). During the pretest, the children were asked to identify the eight objects by pointing to them and stating their function. Children who were unable to identify the pretest objects were not allowed to continue in the experiment ($n = 3$).

Action pantomime task. Immediately following the pretest, all objects were removed and the experiment began. Children were asked to pantomime the use of the eight objects from the pretest. The children received the same general directions for each object and the task presentation involved the addition of a ‘hold’ condition along with the traditional ‘action’ condition. In addition, a puppet named Stuart was used so that the children could pantomime the gestures to someone other than the experimenter. The children were told that Stuart would try to guess what they were pretending. It was expected that the child would be more likely to provide the best pantomime if they knew the puppet must guess what they were pretending.

All children were asked to both hold and to perform actions with the objects. For example, for the toothbrush, the child would be told: “Pretend you are brushing your teeth with a toothbrush so that Stuart can guess what you are pretending <child performs action>. Now pretend you are holding a toothbrush so that Stuart can guess what you are holding <child performs action>." All eight objects were presented in a random order for each child and the order of which condition was presented first (action or hold) was counterbalanced.

Coding. In keeping with the standard coding from prior research, we used two basic response categories:

1. BPO representation, in which the child substituted a body part for the object involved in the pantomime or made contact with an object (such as a table or a plastic nail) or themselves.
2. IO representation, in which the child symbolically represented the object by giving significant evidence that they were imagining an absent object.

This necessitated leaving a space in the hand for the object, not making contact with the self or other objects, and not providing a body part as an anchor. In addition, three other response categories were used to provide a descriptive analysis. Children were coded as "no response" if they did not pantomime a response. Two other categories were used to denote children who began a response in one way but corrected that response and ended in another way. Thus, they were coded as "BPO into IO" or "IO into BPO."

For the hold condition the child was only coded as producing an IO substitution if they left room in their hand for the object. In many cases, it was very possible that children were imagining absent objects without leaving a space for the object but if there was no evidence of an IO substitution, they were coded as producing a BPO substitution. This resulted in a conservative scoring of IO responses in the hold condition, thus working against our hypothesis that the hold condition would result in more IO responses. Children were also coded as IO for the hold condition if they imagined holding the entire object. For example, one child pretended to hold a saw by placing both palms upward and pushing them forward to "show" the entire saw to Stuart.

Prior research has also maintained a distinction between self-directed and other-directed pantomimes (Overton & Jackson, 1973; Suddendorf et al., 1999; Taylor & Carlson, 1997). Self-directed pantomimes included combing hair, drinking juice, talking on the telephone, and brushing teeth; other-directed pantomimes included hammering a nail, sawing wood, drawing a picture, and shoveling sand. All responses were coded immediately.

Results

Reliability analysis. Three response types accounted for a very small percentage of total responses in both conditions (for action: no response = 2%, IO into BPO = 4%, BPO into IO = 1%, BPO = 60%, and IO = 33%; for hold: no response =

3%, IO into BPO = 4%, BPO into IO = 1%, BPO = 37%, and IO = 54%). Thus, to simplify the analysis, children were given a 1 for an IO response or a BPO into IO response (because they completed the action with an IO response). Children were given a 0 for no response, a BPO response, and an IO into BPO response (because they completed the action with a BPO response). To collapse individual scores into one total score, a reliability analysis to see if all eight objects were internally reliable was done for both the action and hold conditions. For both conditions, the objects were internally reliable (KR20 = .8209 for action; KR20 = .8350 for hold). The dependent variable for subsequent analyses was the number of IO substitutions between 0 and 8.

Age-group and pantomime condition analysis. A repeated measures analysis of variance (ANOVA) for age × condition × order was performed. There was no effect for order of pantomime condition ($p = .58$) and no interactions. A second analysis was conducted without condition order as a variable. A repeated measures 3 (age) × 2 (condition: action vs. hold) × 2 (sex) ANOVA using a planned contrast for a linear effect of age revealed a significant linear effect of age, $F(1, 79) = 23.75$, $p < .001$. In support of the main hypothesis of this study, there was a significant main effect of pantomime condition, $F(1, 79) = 34.05$, $p < .001$, favoring the hold condition over the action condition. A pairwise effect-size analysis (Cohen, 1988; Rosenthal, Rosnow, & Rubin, 2000) revealed a large effect ($d = 1.32$, $r = .55$). There were no significant interactions and no effect of sex ($p = .24$). Figure 3 shows the mean number of IO substitutions. The means and standard deviations increased with age in both the action (3-year-olds: $M = 1.38$, $SD = 1.63$; 4-year-olds: $M = 2.81$, $SD = 2.38$; 5-year-olds: $M = 4.18$, $SD = 2.67$) and hold (3-year-olds: $M = 2.96$, $SD = 2.57$; 4-year-olds: $M = 4.59$, $SD = 2.66$; 5-year-olds: $M = 5.95$, $SD = 2.01$) conditions.

Past research has also found a difference between self-directed object pantomimes and other directed object pantomimes favoring the earlier development of self-directed pantomimes (Overton & Jackson, 1973; Suddendorf et al., 1999; Taylor & Carlson, 1997). In this study, consistent with earlier research, children performed significantly more IO substitutions in self-directed pantomimes ($M = 1.69$, $SD = 1.48$) than in other-directed pantomimes ($M = 1.04$, $SD = 1.29$), $t(84) = 4.82$, $p < .001$. This effect was also found in the hold condition (self-directed: $M = 2.42$, $SD = 1.41$; other-directed: $M = 2.02$, $SD = 1.47$), $t(84) = 3.68$, $p < .001$. Self and other were correlated for both action and hold conditions ($r = .59$, $p < .001$, $r = .76$, $p < .001$, respectively).

Discussion

One aim of this study was to further explore the developmental course of children's performance on the action pantomime task. In the original Overton and Jackson

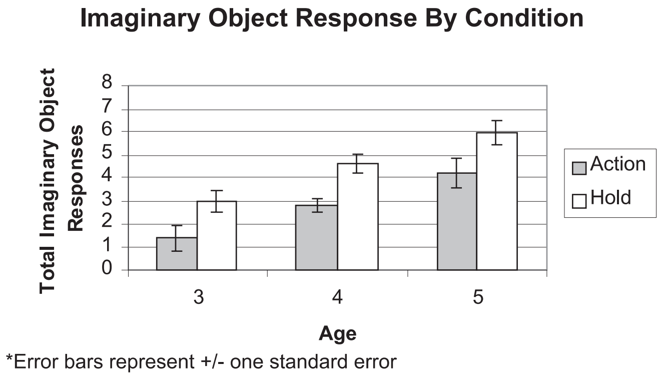

FIGURE 3 Study 1: Mean number of imaginary object responses for eight pantomimed objects in both the hold and action conditions, across three age groups.

(1973) study, children did not produce IO representations in the majority of their responses until 8 years of age. This study supports that finding; 5-year-olds responded with IO substitutions in the action condition about 50% of the time, on average. As this does not indicate ceiling performance, it would be incorrect to suppose that children are performing at the level of adults on this task. Boyatzis and Watson (1993) found that 5-year-olds were producing IO substitutions in 69% of their responses and argued that Overton and Jackson underestimated 5-year-old's representational skill. However, in a study by O'Reilly (1995), 5-year-olds produced IO substitutions in 59% of their responses, whereas adults produced them in 87% of their responses. This finding, along with the findings from this study, support Overton and Jackson's original claim that the development of gestural symbolic representation may continue for some years beyond age 5 before reaching adult levels.

The principal hypothesis of this study was the prediction that children would produce more IO substitutions in the hold condition than the action condition. The results support the hypothesis and this effect is present across all three age groups. The significant difference between the action and hold conditions, with the associated main effect for age, yields support for the position that performing symbolic actions with symbolic objects requires a more advanced level of symbolization and, we would argue, one that necessitates the simultaneous coordination of symbolic representations.

In the beginning of this article, we suggested that children who cannot coordinate dual symbolic representations will produce a simplifying body part anchor for the symbolic object. The similarity in the shape of the body part to the object (e.g., a finger retains the general shape of a toothbrush) serves as an anchor by highlighting certain salient features of the object to be represented, freeing the child to simultaneously represent the functional use of the object in pantomime. In the same way, diminishing the complexity of the action representation (e.g., asking a child to "hold" a toothbrush) facilitates the production of symbolic substitutions because the functional use of the object does not need to be represented.

This required coordination has an analogue in the findings at earlier developmental levels. DeLoache and Smith (1999) argued that children's successful performance in the model-room search task requires a coordinated representation between the model and the room. Of interest, although children at 3 years of age can pass the task using a model as the symbol for the room, 2½-year-old children cannot use the model. However, increasing the similarity of the model to the room (by manipulating the size and surface appearance of the model) aides in performance (DeLoache, Kolstad, & Anderson, 1991; Marzolf & DeLoache, 1994) and 2½-year-old children can pass the task if the symbol is simplified from a model to a video representation or picture representation (DeLoache, 1987; Troseth & DeLoache, 1998). This simplification of the representation is analogous to the simplification of representations in the action pantomime task. However, in the latter case the simplification impacts on the coordination of two dual representations; in the DeLoache tasks, the situation entails the coordination of a single dual representation.

STUDY 2

A prediction made by both the LOC and the Müller and Overton models is that the ability to coordinate representations in one domain should extend to other domains. Thus, one goal of this set of studies is to explore whether the reflective symbolic competence required for using imaginary objects in action pantomime is also important in other cognitive domains. Frye, Zelazo, and colleagues (Frye, Zelazo, & Burack, 1998; Frye, Zelazo, & Palfai, 1995; Zelazo & Frye, 1997, 1998) have explored the psychological processes of problem solving and representation under the rubric of executive function. These investigators hypothesize that successful performance on rule use tasks requires a reflective level of symbolization that permits the coordination of rule representations.

In one rule use task, the standard version of the DCCS task, children are shown cards with pictures that vary on two dimensions (e.g., color and shape). The children are asked to sort the cards first by one dimension (i.e., the preswitch sort) and then switch rules and sort by the second dimension (i.e., the postswitch sort). Most 3-year-olds can sort by the first rule but perseverate and continue to sort on the first dimension after the rule has changed, whereas most 4- and 5-year-olds successfully switch rules (Zelazo, Frye, et al., 1996).

According to Frye, Zelazo, and colleagues (Frye et al., 1995), the difficulty for the 3-year-old occurs when the child must coordinate the rules for the preswitch sort with the rules of the postswitch sort. That is, 3-year-olds are unable to reflect on the two-rule system and thus fail to switch from the old rule to the new rule

(Zelazo & Frye, 1997). This is analogous to the action pantomime task, where the 3-year-old cannot coordinate both dual representations to perform symbolic IO substitutions. According to both the Müller and Overton and LOC models, a new level of representation is reached by 4 or 5 years of age. At this time, children can switch flexibly in the DCCS, presumably because they attain a level of reflective consciousness allowing for the use of a higher order rule to coordinate the preswitch and postswitch rules. Similarly, at 4 to 5 years, children begin using IO substitutions with some regularity on the action pantomime task.

In Study 2, we again focus on the action and hold conditions of the pantomime task and explore these in the context of performance on the DCCS. One aim is to replicate the difference between the action and hold conditions discovered in Study 1. The second aim is to explore the relation between action pantomime and the DCCS. The relation of action pantomime and the DCCS only has been explored in one other study (Carlson & Moses, 2001) and there the relation was measured in an indirect fashion. Carlson and Moses compared action pantomime with a composite measure of inhibitory control, in which the DCCS was one of 10 components. The relation of action pantomime to this composite measure was significant but small. Because the study did not make a direct assessment of the relation, further investigation is warranted. Study 2 also allows us to attempt to replicate the findings from Study 1 and, furthermore, because children in this study participate in both the action and hold conditions of the action pantomime task, we are able to look at the relation of each to the DCCS.

Method

Participants. Participants were 103 predominately White children from middle-class neighborhoods attending local preschools and day care centers in the Philadelphia area. These children were divided into three age groups: twenty-one 3-year-olds (*M* age = 41 months, range = 37–47 months), sixty-two 4-year-olds (*M* age = 54 months, range = 48–59 months), and twenty 5-year-olds (*M* age = 62 months, range = 60–67 months). The children in this study were taken from a sample of children who completed tasks for another study. Because the data collection took place in the context of data collection for another study, only a subset of these children (*n* = 42; *M* age = 56 months; range = 37–67 months) completed the standard version of the DCCS. Boys and girls were equally represented within each age group. An additional 2 children did not complete the pretest for the action pantomime; 3 did not complete at least seven preswitch trials of the DCCS.

General design. The procedure for the action pantomime task was exactly the same as in Study 1. The experimenter was the same as in Study 1, and coding criteria remained the same. A subset of children also received the DCCS (*n* = 42).

DCCS. For the DCCS, we followed the method outlined in Zelazo, Frye and colleagues (1996). One set of laminated cards was used containing 2 target cards (e.g., a blue rabbit and a red boat) and 18 test cards (e.g., red rabbits and blue boats). The task involved a preswitch and a postswitch phase, and half of the children sorted by color first and half by shape first.

One target card was attached to each of the trays. The children received the rules for separating test cards by one dimension (e.g., "All the red ones go in this box, but only blue ones go in this box.") and the child watched as two practice trials were sorted. The children were asked to sort the remaining 16 cards. On each of the preswitch trials, children were reminded of the rules and asked "Where does this go in the _____ (e.g., color) game?" Children were given feedback in the preswitch trials. After eight trials, the experimenter told the children the postswitch rules. They were told, for example, "Okay, now we are going to switch and play a new game, the shape game. We're not going to play the color game any more. No way. In the shape game, all the rabbits go in this box but only boats go in this box." Children then sorted eight postswitch trials. For all trials, the children were reminded of the rule, but they were not given feedback about whether they sorted correctly. Unlike in Zelazo and colleagues (1996), knowledge questions were not asked in this study.

Results

Age-group and pantomime condition analysis. Three response types accounted for a very small percentage of total responses in both conditions on the action pantomime task (for action: no response = 2%, IO into BPO = 1%, BPO into IO = 1%, BPO = 53%, and IO = 43%; for hold: no response = 2%, IO into BPO = 3%, BPO into IO = 1%, BPO = 40%, and IO = 54%). To collapse individual scores into one total score, a reliability analysis was done for both the action and hold conditions. The objects were internally reliable for both the action (KR20 = .8401) and hold (KR20 = .7519) conditions.

For the pantomime action task repeated measures age 3 (age) × 2 (condition: action vs. hold) × 2 (sex) ANOVA was computed. A planned contrast for a linear effect of age revealed a significant linear effect of age, $F(1, 97) = 10.92$, $p = .001$. In support of the representational coordination hypothesis described earlier, there was significant main effect of pantomime condition, $F(1, 97) = 7.66$, $p < .01$, with a greater mean for the hold condition. A pairwise effect-size analysis revealed a moderate effect ($d = .56$, $r = .30$). There were no significant interactions and no effect of sex ($p = .45$). The mean number and standard deviations of IO substitutions increased with age in both the action (3-year-olds: $M = 2.19$, $SD = 2.80$; 4-year-olds: $M = 3.54$, $SD = 2.55$; 5-year-olds: $M = 5.02$, $SD = 2.05$) and hold (3-year-olds: $M = 3.79$, $SD = 2.75$; 4-year-olds: $M = 4.18$, $SD = 2.38$; 5-year-olds: $M = 5.41$, $SD = 1.69$) conditions (see Figure 4).

Action pantomime and DCCS analysis. An analysis of correlations between the action pantomime task and the DCCS (with the DCCS dependent variable as the number of correct postswitch sorts) revealed significant one-tailed correlations between both the action condition, $r(42) = .25$, $p = .05$, and the hold condition, $r(42) = .30$, $p < .05$. However, the correlations became nonsignificant when age was partialled for action, $r(42) = .12$, $p = .23$, and for hold, $r(42) = .19$, $p = .12$.

As in Study 1, children performed significantly more IO substitutions in self-directed pantomimes ($M = 2.20$, $SD = 1.47$) than in other-directed pantomimes ($M = 1.35$, $SD = 1.43$), $t(102) = 6.82$, $p < .001$. This effect was also found in the hold condition (self-directed: $M = 2.39$, $SD = 1.39$; other-directed: $M = 1.99$, $SD = 1.27$), $t(102) = 3.18$, $p < .01$. Neither self- nor other-directed pantomimes were correlated with passing the DCCS in the action condition for self, $r(42) = .21$, $p = .10$, and for other, $r(42) = .24$, $p = .06$, or the hold condition for self, $r(42) = .23$, $p = .07$, and for other, $r(42) = .10$, $p = .27$. Both self and other directed actions were correlated with each other for both conditions (smallest $r = .21$, $p = .01$).

Discussion

The findings of Study 2 replicated the age-related linear increase in the number of IO substitutions found in Study 1. In the action condition, 5-year-olds produced symbolic imaginary substitutions on approximately 60% of the task trials. Similarly, the significant differences between the action and hold conditions were repli-

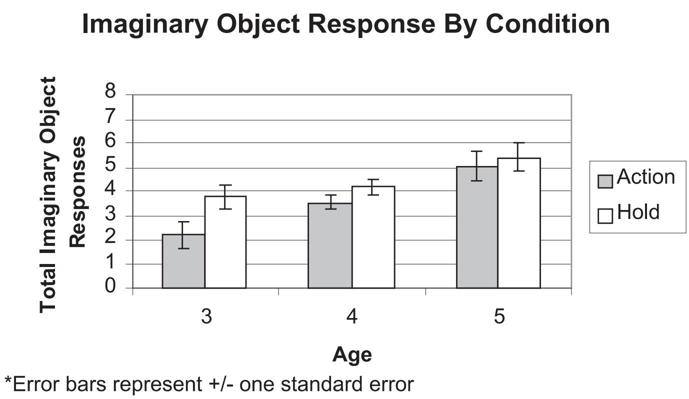

FIGURE 4 Study 2: Mean number of imaginary object responses for eight pantomimed objects in both the hold and action conditions, across three age groups.

cated for this sample, thus again supporting the hypothesis that the action pantomime task entails a reflective level coordination of symbolic representations. Children produced more IO substitutions when the condition required a simple holding of an object rather than performing an action with that object.

The results of the correlation analysis demonstrated that performance on both the action and hold conditions were related to the DCCS. However, both correlations became nonsignificant when age was partialled. This finding is consistent with Carlson and Moses's (2001) earlier study. Although not reported in the published article, Carlson and Moses (S. Carlson, personal communication, September 17, 2003) found a modest association between the DCCS and the action pantomime, which became nonsignificant when age was partialled. However, caution is needed in interpreting age-partialled correlations. It needs to be remembered that age cannot be an explanation for developmental change. Age is simply a marker for time and time, in and of itself, has no causal properties. Many factors covary with age and some of these factors, rather than age per se, must constitute the mechanism or mechanisms. When age is partialled out of a correlation, all of these potential mechanisms may also be removed. Thus, nonsignificant age-partialled correlations do not necessarily establish that performance across tasks is unrelated to a common underlying mechanism. Consequently, we would argue that the finding of a modest relation between the action pantomime and the DCCS offers some support for the supposition that DCCS and action pantomime performance may be reflections of similar underlying processes (i.e., the reflective coordination of symbolic representations).

However, the modest size of the simple correlations between the action pantomime and the DCCS still requires an explanation, and this explanation is quite possibly found in factors that are specific to each task. For example, recent research has suggested that both negative priming (Müller, Dick, Gela, Overton, & Zelazo, 2004; Zelazo, Müller, Frye, & Marcovitch, 2003) and inhibitory control (Kirkham, Cruess, & Diamond, 2003; Kirkham & Diamond, 2003; Towse, Redbond, Houston-Price, & Cook, 2000) play a role in performance on the DCCS. These factors do not, however, appear to be relevant to action pantomime performance. Further discussion of the role of individual task factors are presented in the General Discussion.

STUDY 3

Study 3 has two aims. First, the reliability of the developmental course of performance on the action pantomime task found in Studies 1 and 2 is again assessed. Second, this study further examines possible relations among action pantomime and other cognitive tasks that are also understood to entail the reflective coordination of symbolic representations. In the theory of mind literature, the coordination of conflicting symbolic representations has been hypothesized to account for success on both the standard false belief and appearance–reality tasks (Flavell, 1986; Flavell, Green, & Flavell, 1986; Wimmer & Perner, 1983). The standard false belief task (Wimmer & Perner, 1983) presents the child with a conflict between the child's representation of reality and the other person's potential representation of reality. These symbolic representations must be reflected on within a coordinated context for successful performance. In the standard appearance–reality task (Taylor & Flavell, 1984), children are shown deceptive objects that can be mentally represented in conflicting ways, and representations of how the object appears to the self versus how it really is must be coordinated at a reflective level of symbolic representation.

Earlier research has established relations among performance on the appearance–reality and false belief task (Gopnik & Astington, 1988). Frye et al. (1995) examined the relation between performance on the DCCS and the appearance–reality and false belief tasks and found significant correlations among tasks, which supported their hypothesis that both theory of mind tasks and the DCCS task require the use of coordinated representations. This finding was replicated with other typically developing children (Andrews, Halford, Bunch, Bowden, & Jones, 2003; Carlson & Moses, 2001), children with Down syndrome (Zelazo, Burack, Benedetto, & Frye, 1996), and children with autism (Colvert, Custance, & Swettenham, 2002; Zelazo, Jacques, Burack, & Frye, 2002). These empirical findings support the argument for the necessity of reflecting on coordinated systems in both theory of mind and rule use tasks. For action pantomime, Carlson and Moses (S. Carlson, personal communication, September 17, 2003) found a small but significant relation between theory of mind and the action pantomime task, but this relation disappeared when age was controlled. However, Suddendorf and colleagues (1999) found that success on false belief and appearance–reality is correlated with more IO substitutions on the action pantomime task, even after accounting for the effects of age.

Given these theoretical and empirical findings concerning the coordination of symbolic representations at a reflective level, Study 3 examines the extent to which the coordination of representations is necessary for the cognitive competences that emerge at around 4 years of age and are expressed in action pantomime, theory of mind and executive function or rule use tasks. Under the hypothesis that an increase in reflective competence will translate to success on tasks in these domains, associations are expected among the action pantomime task, the DCCS, and theory of mind tasks.

Method

Participants. Participants were 107 predominately White children from middle-class neighborhoods who attended nursery schools in central New Jersey. The sample included thirty-five 3-year-olds (*M* age = 42 months, range = 32–47), forty-three 4-year-olds (*M* age = 53 months, range 48–58), and twenty-nine 5-year-olds (*M* age = 64 months, range 59–70). Boys and girls were approximately equally represented within each age group. An additional 5 children failed the action pantomime pretest and 3 children did not pass the preswitch phase of the DCCS.

General design. Children completed four tasks: (a) an action pantomime task, (b) the DCCS, (c) the appearance–reality task, and (d) the false belief task. The children were tested individually in a quiet room at the preschool and were seen in two sessions. The order of task presentation remained constant. The first session consisted of the DCCS task followed by the action pantomime and the second consisted of the theory of mind tasks (appearance–reality followed by false belief).

Action pantomime task. For Study 3, the Stuart manipulation was not used, and children only completed the action condition of the task. The experimenter differed from Studies 1 and 2 and only three categories of response were used in this study: IO, BPO, and no response. All responses were coded immediately. The experimenter and another coder agreed on the category of response on 91% of the trials based on video recording of a subset of participants (n = 27). The experimenter's coding was used for all children.

DCCS. The procedure for the DCCS was the same as the procedure in Study 2, except 6 preswitch and 6 postswitch cards were used. In addition, pictures of yellow bears and red cars served as target cards, and red bears and yellow cars as test cards.

False belief task. The standard false-belief task was administered following Wimmer and Perner (1983) using three sets of characters: Elmo, Mary, and Piglet. The children were introduced to the characters and were presented with the false belief scenario. For example, children were told "Piglet has a piece of candy and he puts it in his basket and goes outside to play. 'Naughty Tigger' comes and takes the candy out of the basket and puts it in the red box." Following this story scenario, children were asked memory and reality questions ("Where did Piglet put the candy," "Where is the candy now?"). Finally, the children were asked the false belief question about where Piglet would look for the candy. To pass the task, the children had to pass both memory and reality questions and say that Piglet would look for his candy in the basket.

Appearance–reality task. Three deceptive items were administered as in Gopnik and Astington (1988): a crayon box with candy inside, a sponge that was painted to look like a rock, and a candle that looked like a lemon. Children were told they were going to play a game and that they would be asked questions about some of the objects in the game. Each item was then presented without revealing the deceptive state of the object and the children were told to look at the object. Then the true nature of the object was revealed by allowing the children to examine it. The experimenter took the object back and asked two appearance–reality questions, "What does this look like?" (appearance) and "What is this really?" (reality). To pass the task, the child had to answer what the item looked like and what it really was.

Results

Action pantomime task. Items coded as no response accounted for a very small percentage of the number of total responses (5%) and the analysis proceeded as before. All objects were internally reliable (KR20 = .90) and all eight objects were summed.

To discover whether this study replicated the findings of increasing IO use with age, a 3 (age) × 2 (sex) ANOVA using a planned contrast for a linear trend for age was performed. There was a significant linear effect for age, $F(1, 101) = 30.87$, $p < .001$, and no other main effects or interactions. The mean number and standard deviation of IO substitutions increased with age (3-year-olds: $M = .63$, $SD = 1.73$; 4-year-olds: $M = 2.30$, $SD = 2.42$; 5-year-olds: $M = 4.1$, $SD = 3.7$) but on average, 5-year-olds did not produce more than 51% of their responses as IO substitutions. In this study, consistent with earlier findings, children produced significantly more IO substitutions in self-directed pantomimes ($M = 1.26$, $SD = 1.51$) than other-directed pantomimes ($M = .98$, $SD = 1.40$), $t(106) = 3.05$, $p < .01$.

DCCS. Only children who sorted four out of five preswitch cards correctly were included in the analysis. Children were considered to have passed the card sort if they sorted four out of five postswitch cards correctly. Results replicated past research (Zelazo, Frye et al., 1996). Very few 3-year-olds (5 out of 35; 14%) used the postswitch rules in the postswitch phase. In contrast, a majority of 4-year-olds (30 out of 43; 70%) and a majority of 5-year-olds (25 out of 29; 87%) successfully used the postswitch rules. There was a significant relation between age and performance on the DCCS, $\chi^2(2, N = 107) = 38.78$, $p < .001$. Performance on the DCCS was not related to sex.

Standard theory of mind tasks. Due to attrition between testing sessions, some children who completed the DCCS and action pantomime did not complete the theory of mind tasks ($n = 8$). An additional two children refused to complete the false belief task after completing appearance–reality. Any analyses involving these variables did not include children with missing data. For false belief, children were given a score of one for each trial if they successfully reported the character's initial belief. For appearance–reality, in accordance with Gopnik and Astington (1988) and Frye and colleagues (1995), children were given a score of one if they answered both what the object appeared to be and what it really was.

Three scenarios (Elmo, Mary, and Piglet) were used to assess children's understanding of another person's beliefs. Past studies reported increasing success on the task as age increases (Gopnik & Astington, 1988; Wellman et al., 2001; Wimmer & Perner, 1983). As with past research, the percentage correct increased with age across all scenarios (for Elmo: 3-year-olds = 38%, 4-year-olds = 65%, and 5-year-olds = 64%; for Mary: 3-year-olds = 23%, 4-year-olds = 62%, and 5-year-olds = 57%; for Piglet: 3-year-olds = 26%, 4-year-olds = 62%, and 5-year-olds = 67%). The scores for all three scenarios were correlated (smallest $\varphi = .71$, $p < .001$) and summed to yield a false belief score between 0 and 3 for the analysis of correlations.

For appearance–reality, in the crayons–candy condition, 4-year-olds performed worse than both 3- and 5-year-olds (3-year-olds = 41%, 4-year-olds = 14%, 5-year-olds = 46%). In contrast, on both the rock–sponge and lemon–candle conditions, the percentage correct increased with age (for rock–sponge: 3-year-olds = 19%, 4-year-olds = 34%, and 5-year-olds = 47%; for lemon–candle: 3-year-olds = 15%, 4-year-olds = 31%, and 5-year-olds = 54%). Performance on the crayons–candy condition was significantly correlated with the rock–sponge condition ($\varphi = .25$, $p < .01$) but not with the lemon–candle condition ($\varphi = .18$, $p = .08$). Rock–sponge was correlated with lemon–candle ($\varphi = .42$, $p < .001$). Because the age trend for the crayons–candy condition does not replicate past research, and because it did not correlate with the lemon–candle condition, we felt this might add error to the analysis, and thus we report the correlations in Table 1 with the crayon–candy condition excluded. However, with the crayon–candy condition included, the appearance–reality one-tailed correlations are as follows: with age, $r(99) = .32$, $p = .001$, with action pantomime, $r(99) = .20$, $p = .02$, with DCCS, $r(99) = .20$, $p = .02$, and with false belief, $r(97) = .26$, $p = .005$.

Relations among the tasks. Simple and age-partialled correlations among the tasks are shown in Table 1. Significant correlations exist among all tasks and between all tasks and age. However, significant correlations among tasks decrease and disappear when the effect of age is controlled. Correlations only remained significant between the false-belief task and the DCCS (analyzed as the number of correct postswitch sorts) and between false belief and appearance–reality. These significant correlations replicate past findings, though past studies have found larger correlations among tasks (Carlson & Moses, 2001; Frye et al., 1995; Gopnik & Astington, 1988). Because partialling age among all three groups may hide possible correlations within age groups, within age correlations were analyzed (see Table 1).

TABLE 1
Simple, Age-Partialled, and Within-Age Correlations Among Tasks in Study 3

Correlations	*Action Pantomime*	*DCCS*	*False Belief*	*Appearance–Reality*
Simple				
Age	.49***	.63***	.31***	.37***
Action pantomime	—	.34***	.19*	.18*
DCCS		—	.42***	.22**
False belief			—	.29**
Appearance-reality				—
Age-partialled				
Action pantomime	—	–.01	–.04	–.03
DCCS		—	.31***	.05
False belief			—	.21*
Appearance-reality				—
3-year-olds: simple				
Action pantomime	—	.11	–.13	–.11
DCCS		—	.27	–.08
False belief			—	–.02
Appearance-reality				—
4-year-olds: simple				
Action pantomime	—	–.04	.05	–.07
DCCS		—	.23	.25
False belief			—	.30*
Appearance-reality				—
5-year-olds: simple				
Action pantomime	—	.17	.15	.08
DCCS		—	.37*	–.23
False belief			—	.34*
Appearance-reality				—

Note. DCCS = Dimensional Change Card Sort. All p values are one-tailed.
* $p < .05$. ** $p < .01$. *** $p < .001$.

Other researchers have examined relations between the DCCS and action pantomime and a theory of mind composite score (Carlson & Moses, 2001; Taylor & Carlson, 1997), as well as the relations of theory of mind and self-and other-directed pantomimes (Suddendorf et al., 1999; Taylor & Carlson, 1997). In this study, the DCCS and action pantomime were related to the theory of mind composite, which combined appearance–reality without the crayon–candy condition, and false belief, $r(97) = .42$, $p < .001$ and $r(97) = .22$, $p < .05$, respectively. Though the DCCS relation maintained significance when the effects of age were removed, $r(97) = .24$, $p < .01$, the relation between action pantomime and the theory of mind composite did not. Both self- and other-directed actions were related to the total pantomime score and each other. In addition, self-directed actions were significantly related to appearance–reality, $r(97) = .19$, $p <$

.05, and the DCCS, $r(107) = .32$, $p < .001$. Other-directed actions were related to false belief, $r(97) = .24$, $p < .01$, and the DCCS, $r(107) = .32$, $p < .001$. With the exception of the relations to the total pantomime score and each other, none of the relations among tasks to self- and other-directed actions maintained significance when age was partialled out.

Discussion

Study 3 replicates the age trend for the action pantomime task found in Studies 1 and 2. In addition, although the experimenters, the sample of children, and the schools from which the children were drawn all differed from the first two studies, the means for the 4- and 5-year-olds in the action conditions were virtually identical (especially when compared to Study 1). Again, 5-year-olds produced IO substitutions between 50% and 60% of their responses, which is not ceiling performance.

The findings also provided some weak support for the second aim of the study, determining whether success on the action pantomime task, theory of mind, and the DCCS task require the coordination of symbolic representations at a reflective level. A significant relation was found between the DCCS and false belief and between false belief and appearance–reality. This replicates past findings (Carlson & Moses, 2001; Frye et al., 1995; Gopnik & Astington, 1988; Taylor & Carlson, 1997). More important, the findings demonstrated a modest significant relation between action pantomime and the DCCS and weak but significant relations between action pantomime and theory of mind.

The relation between action pantomime and theory of mind became nonsignificant when age was partialled out, and when correlations were considered within ages. Thus, our findings are compatible with and Taylor and Carlson (1997), who did not partial out age. The findings are also compatible with Carlson and Moses (2001), who found that correlations between action pantomime and theory of mind became small and nonsignificant when age was partialled (S. Carlson, personal communication, September 17, 2003). These findings are not, however, compatible with Suddendorf and colleagues (1999), who continued to find a significant relation between action pantomime and theory of mind when age was partialled out. The design of this study also allowed for the comparison among tasks within age groups. In this case, the relations between false belief and appearance–reality remained consistently significant and the DCCS remained related to false belief in 5-year-olds. Again, action pantomime did not appear to be strongly related to either theory of mind or the DCCS. The reason for the lack of a relation between action pantomime and theory of mind and the DCCS with age removed from the equation is open to several interpretations that are discussed in the following paragraphs.

GENERAL DISCUSSION

These studies have focused on the development of symbolization between 3 and 5 years of age. Overall, the results support the hypothesis that during these years symbolic competence moves from a symbolic to a reflective symbolic level of representational functioning. The strongest support for the development of a reflective level of symbolic representation comes from the action pantomime task. Across all studies, the use of imaginary object substitutions in pantomime increased with age. In addition, the mean scores on this task remained relatively consistent across all three studies, which utilized different experimenters and different samples of children. Most important, Studies 1 and 2 demonstrated an increased production of IO substitutions when the dynamic action component of the pantomime was reduced to the static action of holding an object. We suggested earlier that the child produces a body part to anchor the object representation because of the inability to adequately coordinate the dual symbolic representation of the object with the dual symbolic representation of the action. In this case the body-part anchor is essentially a simplification of the object representation. The addition of a hold condition in these studies simplifies the action representation (i.e., effectively reducing, the dual representational quality of the action component). Being thus freed of the need to coordinate a functional action dual representation with the object dual representation, the child no longer requires the body part anchor for the object representation and produces the imaginary symbolic object (i.e., the object dual representation).

In line with this research, Lillard (1993) also argued that the coordination of dual representations emerges during the preschool years. According to Lillard, two skills in object substitution emerge with development. First, with objects in view, children become capable of entertaining two representations that are increasingly different in both appearance and function (i.e., banana = phone → toy car = phone). Second, children also become better at entertaining multiple sets of these dual representations (see Fein, 1975). When objects are absent, as in these studies, children move from relying on embodied anchors to employing symbolic object representations. This development occurs as children improve in their ability to coordinate the functional action representation with the object representation.

The results of our studies also have important implications for future investigations of the development of symbol coordination. First, early symbolic object production in the hold condition suggests that this condition is a relatively sensitive measure of the younger child's emerging symbolic capacity. Second, although Boyatzis and Watson (1993) argued that the symbolic progression from BPO representations to IO representations is completed in the preschool years, these findings, along with earlier research (Overton & Jackson, 1973) suggested that the development of coordinated symbolic representations is a complex, protracted process that extends beyond the preschool period. Findings from other domains of symbolic representation, such as the development of the understanding of external spatial representations (e.g., maps, models, and photographs) support this kind of extended development (Beilin, 1999; Liben, 1999; Liben & Downs, 1989). Research in the area of children's developing use of maps has led to the conclusion that even early elementary school children may not fully appreciate the basic properties of symbols (Liben & Downs, 1992). Consistent with this argument, a number of investigators argued that the symbolic function progresses through a series of levels of understanding (Bialystok, 1992).

Along with finding support for levels of symbolic representational competence, in line with other studies (Boyatzis & Watson, 1993; O'Reilly, 1995) we found variability in children's performance at each level. This variability is undoubtedly related to several factors, including the familiarity of objects and actions. The general finding that symbolic performance with actions directed toward the self emerges earlier than actions directed toward the external world is likely at least partially accounted for on the basis of the child's greater familiarity or experience with actions and objects directed toward the self.

This research was also concerned with the issue of whether the reflective symbolic competence required in the action pantomime task is also central to other aspects of cognition, specifically to executive function as measured by the DCCS and to the child's emerging theory of mind as measured by the appearance–reality and false belief tasks. Studies 2 and 3 revealed a modest relation between action pantomime and the DCCS and action pantomime and theory of mind. We believe that lack of a stronger relation centers on the subtle distinction between the simultaneous coordination of symbolic representations required by the action pantomime task and consecutive coordination of symbolic representations required by the DCCS and theory of mind. Consecutive coordination is illustrated by the standard DCCS, which requires that a child switch from a judgment about color (shape) to a judgment about shape (color). Similarly, though appearance–reality and false belief may involve the consideration of alternative conflicting representations of reality (Gopnik & Astington, 1988), these representations are not necessarily spatially and temporally linked. Conversely, the action pantomime task requires the production of a physical response, which necessarily demands that both an action dual representation (e.g., symbolic brushing) and an object dual representation (e.g., symbolic toothbrush) be produced and remain active simultaneously.

Empirical support of this interpretation has been mixed and further investigations are needed. On the one hand, in support of this interpretation, Frye and colleagues (1995, Exp. 3) demonstrated that a modified DCCS requiring the simultaneous sorting of two dimensions is more difficult than the standard. Furthermore, Frye and colleagues found that only the consecutive version was correlated with theory of mind. On the other hand, very recent work focusing on the similarities and differences between the simultaneous and consecutive versions of the DCCS

(Andrews et al., 2003) found significant relations between both the standard and simultaneous versions of the DCCS and false belief but not between either version and appearance–reality when age is controlled. This issue of the child's developing capacity to simultaneously hold and manipulate representations in mind has been discussed by several investigators (Chalmers & Halford, 2003; Diamond et al., 2002; Gordon & Olson, 1998; Halford, Wilson, & Phillips, 1998) and this problem clearly deserves further empirical examination.

A second possible explanation that might be put forth regarding the relation between action pantomime and the other tasks entails the potential role of inhibitory processes in task success. Several investigators have argued that success on the DCCS task depends on inhibiting the salient features of the preswitch cards, which become irrelevant in the postswitch phase of the task (Diamond et al., 2002; Kirkham et al., 2003; Perner & Lang, 2002; Towse et al., 2000) or, at least in part, on the disinhibition of previously suppressed information resulting in negative priming (Müller et al., 2003; Zelazo et al., 2003). It also has been argued by some that successful theory of mind performance requires the inhibition of prepotent responses (Carlson et al., 1998, 2002; Diamond et al., 2002; Leslie & Polizzi, 1998; Leslie & Roth, 1993; Moore et al., 1995; Russell, 1996, but see Perner, Lang, & Kloo, 2002, and Tager-Flusberg, Sullivan, & Boshart, 1997). However, for action pantomime, there is no obvious inhibitory component associated with symbolic substitutions. That is, it is not clear what response or representation one would need to inhibit to perform IO substitutions. That the coordination of dual representations does not necessarily demand an inhibitory component is supported by the finding that reducing the demand for response inhibition is not related to success on dual representation tasks (O'Sullivan, Mitchell, & Daehler, 2001; Sharon & DeLoache, 2003). It is worth noting, however, that Carlson and Moses (2001) found a small but significant relation between action pantomime and a composite measure of inhibitory control. Thus, future research needs to consider any potential inhibitory process on the development of the simultaneous coordination of dual representations.

In summary, the findings from these studies suggest a potential central role for levels of reflective symbolic coordination in children's developing symbolic competence. This research suggests that a new level of reflective symbolic competence emerges at around the age of 4 years, but it appears to undergo considerable consolidation beyond the preschool period. It is also clear that further research is needed to explore the relation between the coordination of dual representations required in action pantomime and other cognitive domains.

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