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CROSS MODALITY CORRELATIONS IN THE IMAGERY OF ADULTS AND 5-YEAR-OLD CHILDREN

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ABSTRACT

This research examined visual and auditory imagery in adults and 5-year-old children. We focused on 3 broad issues: 1) parallels between visual and auditory imagery; 2) static and dynamic imagery processes within the visual and auditory modalities; and 3) individual differences in these imagery processes. In Experiments 1 and 2, adults completed a set of four tasks of visual and auditory imagery and self-report measures of imagery. In Experiment 3, the set of imagery tasks was presented to 83 5-year-old children. Although children were less consistent in their imagery use than adults, there were interesting parallels between the children's and adults' performance. Across the 3 experiments, we found little or no relationship between static and dynamic imagery processes within the visual and auditory modalities. In contrast, significant correlations were observed across modality for dynamic imagery. These findings highlight the importance of examining cross-modality parallels in the development of imagery processes.

Mental imagery is most often associated with vision, but imagery can occur in any sense modality. In particular, it is a common experience to hear voices, music, and other sounds with "the mind's ear." There are a number of interesting parallels between imagery in vision and imagery in audition [1-5]. For example, just as visual images contain information about perceived object

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properties such as shape, size, and color [6], auditory images contain information about perceived sounds, including pitch, loudness, and temporal sequence [7, 8]. In addition, both visual and auditory imagery share common neural pathways and processing mechanisms with their corresponding perceptual systems [9-13].

Despite these parallels, the relation between visual and auditory imagery processes is not well understood. An interesting question is whether some aspects of imagery might be shared across the visual and auditory modalities. Past research examining the relation between individual differences in the use of visual imagery and auditory imagery has yielded mixed results. Whereas self-report studies show that individual differences in imagery vividness tend to be correlated across the visual and auditory domains [14], the available behavioral evidence indicates that individual differences in visual imagery and auditory imagery are not related. For example, when Aleman and colleagues compared auditory and visual imagery in musically trained and untrained participants they found that differences in auditory imagery were not associated with similar differences in visual imagery [15]. However, Aleman et al. reported group means for correct performance in the auditory and visual tasks with no assessment of the extent that imagery was in fact used by the participants to perform the tasks [15]. Thus, this study does not address the question of whether extensive use of imagery in the visual modality might be reflected in other modalities as well. One goal of our research was to examine the relation between visual and auditory imagery using both behavioral and self-report measures.

In addition, a primary goal of this research was to examine the relation between visual and auditory imagery from a developmental perspective. Since Piaget and Inhelder's early studies of visual imagery in children [16], researchers have been interested in the role that imagery processes play in cognitive development. However, little is known about the relation between visual and auditory imagery in children. Mirroring the adult literature, most developmental research has focused on visual imagery. Evidence from the most recent studies suggests that visual imagery processes show continuities across development, with similarities between children and adults emerging as early as the preschool years [17, 18]. For example, Kosslyn, Margolis, Barrett, Goldknopf, and Daly compared the performance of 5-, 8-, and 14-year-old children and adults on tasks of visual image generation, maintenance, scanning, and rotation [18]. Although the youngest children were generally less adept at these imagery tasks compared to adults, they showed similar patterns of performance.

Less is known regarding young children's ability to generate, maintain, inspect, and transform auditory images. The few available studies of auditory imagery in children have either examined musical imagery and the role of early musical training in facilitating cognitive development [19-21], or compared the relationship between sensory deprivation (blind or deaf children) and differences in auditory imagery [22-24]. In this research, we extended previous developmental work on basic auditory imagery processes and examined the relation between visual and auditory imagery in both adults and children.

In addition to the comparison of imagery use across modality, we were interested in the extent that imagery use would be related across different types of tasks within a modality. Both visual and auditory imagery appear to be comprised of independent sub-processes [1, 25]. For example, performance on tasks that require the inspection of static visual images shows little or no relationship with performance on tasks that require the transformation of visual images, such as mentally rotating a 3-dimensional figure [10, 25]. In auditory imagery, tasks that involve a temporary phonological store for the comparison of one sound with another do not seem closely related to tasks that involve an articulatory rehearsal process for generating auditory images involving language [26-28]. Accordingly, we used two types of tasks in each modality, one in which static images were compared and one in which images were dynamically transformed. Thus, this research is an extension of past work examining the sub-processes within modalities as well as an investigation of cross-modality correlations in the use of imagery.

EXPERIMENT 1

In Experiment 1, adults were asked to complete a set of imagery tasks that assessed static and dynamic processes in both visual and auditory imagery. In addition to the behavioral imagery tasks, the participants completed a set of questionnaire measures in order to assess self-reported individual differences in both visual and auditory imagery.

Our goal was to develop a set of imagery tasks that ultimately could be used with young children, so all of the tasks involved the comparison or manipulation of the sizes or sounds of common animals. The static visual imagery task was adapted from Moyer's research in which adults were asked to compare animal sizes [29], and the static auditory imagery task was adapted from Intons-Peterson's research in which adults were asked to compare the volume of sounds [30]. Size comparison tasks have been used to assess visual imagery in past research [31-33] and are within the capabilities of preschool-aged children [32].

Dynamic imagery has been assessed with different types of methods in the visual and auditory modalities. Most dynamic visual tasks require mental rotation [6, 34], but mental rotation does not have an obvious analog in the auditory modality and thus was not the best choice for our research. Instead we used a dynamic auditory imagery task adapted from research by Intons-Peterson [30] and then developed an analog of this task for assessing visual imagery. For the dynamic auditory tasks, we asked participants to imagine increasing the volume of one animal sound to match the volume of a louder one. In order to have a parallel measure of dynamic visual imagery, we designed a new task in which participants were asked to mentally match the size of two animals (e.g., imagine a bee growing to the size of an elephant).

Past research indicates that people vary considerably in the extent to which they use images in tasks designed to elicit imagery [35]. For example, when asked to imagine and compare the sizes of common objects, some adults generate and inspect visual images, whereas others tend to rely instead on their knowledge of the relative sizes of the objects [36]. Kosslyn and others assess the use of imagery by examining the correlation between differences in the size or volume of the images being compared and the reaction times to perform the judgments [37]. Thus, in our research we varied the sizes and volumes of the animals being compared. Based on findings from previous research [29, 30, 32], for the static imagery tasks we predicted that reaction time to compare the sizes of two imagined animals or the volumes of two imagined animal sounds would increase as the difference in the animals' size/sound volume decreased. For example, if a person is using imagery when comparing the size of two imagined animals, it should take longer to decide which animal is larger when the size difference is small (a duck compared with a cat) than when it is large (a duck compared with an elephant) [29, 38]. The assumption is that size and volume differences are represented in images and that these differences affect real-time processing [30, 37].

For the dynamic tasks, we predicted that the time needed to mentally match the size or sound volume of two animals would increase as the differences in size or volume increased. For example, when imagining one animal growing to the size of a second animal, it should take longer when the size difference is large (a bee growing to the size of an elephant) than when it is small (a bee growing to the size of a mouse). For all of our tasks, we interpreted the correlations between size/volume differences and reaction times as an index of imagery use.

Method

Participants

Ninety-two undergraduates (71 females and 21 males, mean age 19.1 years, predominantly White) participated in exchange for course credit.

Development of Stimuli

Animal pairs were used as stimuli for the imagery tasks because:

a) they have been used in previous imagery research [37-39];
b) they are familiar to adults and children; and
c) animals vary in both size and the volume of the sounds they make and thus could be used for both the visual and auditory imagery tasks.

In an initial pilot study, 33 college students were given a list of 20 animal names and asked to rate the size and sound volume of the animals on a 7-point scale from very small (i.e., 1) to very big (i.e., 7), and from very soft (i.e., 1) to very loud (i.e., 7). From these data, we selected 10 animals to create a stimulus set of 18 animal pairs that varied in size and volume differences. Four random orders of the animal pairs were used in the experiment.

Procedure

Each participant was tested individually in a 30-minute session. First the experimenter asked participants to generate and describe a visual image of a dog and an auditory image of a dog barking. Based on self-reports, all participants were able to generate and describe these images. Then participants were given the four types of imagery tasks (static visual, dynamic visual, static auditory, and dynamic auditory). Task instructions and stimuli were presented aloud by the experimenter, and participants responded by clicking a computer mouse connected to a laptop computer. After completing the imagery tasks, participants rated the size and sound volume of the animals and completed self-report imagery questionnaires. Table 1 presents a complete list of the animal pairs and their mean differences in size and sound volume.

Static Visual Imagery: Animal Size Comparison [29]—For each of 18 trials, participants imagined 2 animals side by side and decided which one was larger. To begin each trial, the experimenter named the first animal, waited until the participant reported having formed a visual image of it, and then named the second animal. Participants clicked the computer mouse to indicate that they had made the decision and then said the name of the larger animal. Reaction times were measured from the presentation of the second animal name to the participant's mouse click. When the difference in size was small, participants were expected to take longer to decide which animal was larger than when the difference was large [29, 38].

Dynamic Visual Imagery: Animal Size Matching—For each of 18 trials, participants imagined 2 animals side by side and then imagined the smaller animal growing until it was as big as the larger animal. To begin each trial, the experimenter named the larger animal, waited until the participant reported having formed a visual image, and then named the smaller animal. Participants clicked the computer mouse when they had matched the size of the two animals. Reaction time was recorded from the name of the smaller animal to the mouse click. When the size difference between the two animals was large, participants were expected to take longer to imagine the smaller animal growing to the size of the larger animal than when the size difference was small.

Static Auditory Imagery: Animal Sound Comparison (adapted from Intons-Peterson [30])—For each of 18 trials, participants imagined 2 animal sounds and

Table 1. The Mean Size and Volume Differences for Stimuli Used in Experiment 1 (*N* = 92)

Animal pair	Size difference	Animal sound pair	Volume difference
cow-lion	0.03 (0.92)	bee-mouse	0.00 (0.57)
duck-pigeon	0.37 (0.49)	dog-cow	0.33 (1.09)
cat-pigeon	0.64 (0.67)	pigeon-mouse	0.57 (0.77)
pigeon-mouse	0.72 (0.48)	cat-pigeon	1.00 (0.81)
mouse-bee	0.73 (0.45)	duck-pigeon	1.04 (0.76)
dog-cat	0.91 (0.53)	lion-cow	1.26 (1.05)
elephant-cow	1.32 (0.68)	cat-mouse	1.57 (0.75)
cat-mouse	1.36 (0.59)	dog-cat	1.71 (0.81)
cow-dog	1.68 (0.88)	elephant-cow	1.84 (0.98)
dog-mouse	2.27 (0.61)	cow-duck	2.00 (1.04)
lion-cat	2.57 (0.75)	cow-cat	2.03 (1.02)
cow-cat	2.60 (0.85)	elephant-dog	2.16 (1.15)
cow-duck	2.88 (0.77)	dog-mouse	3.27 (0.89)
elephant-dog	3.00 (0.61)	lion-cat	3.29 (0.97)
dog-fly	3.00 (0.61)	dog-fly	3.30 (0.91)
elephant-duck	4.19 (0.42)	cow-fly	3.63 (1.20)
cow-fly	4.68 (0.68)	elephant-duck	3.84 (0.99)
elephant-bee	6.00 (0.00)	elephant-bee	5.43 (1.15)

decided which one was louder. To begin each trial, the experimenter named the first animal sound, waited until the participant reported having listened to an auditory image, and then named the second animal sound. Participants clicked the computer mouse to indicate that they had made the decision and then said the name of the louder animal sound. Reaction time was measured from the name of the second animal sound to the mouse click. When the difference in sound volume was small, participants were expected to take longer to make the loudness discrimination than when the difference was large.

Dynamic Auditory Imagery: Animal Sound Matching (adapted from Intons-Peterson [30])—For each of 18 trials, participants listened to an auditory image of an animal sound and then imagined a second softer animal sound increasing in volume until it was as loud as the first. To begin each trial, the experimenter named the first animal sound, waited until after the participant reported having listened to an auditory image, and then named the second softer animal sound. When the participant had mentally matched the volume of the two animal sounds, he or she clicked the computer mouse. Reaction time was recorded from the name of the softer animal sound to the mouse click. When the difference between the two animal sounds was large, participants were expected to take longer to mentally turn up the volume of the softer sound to the volume of the louder one.

Self-Report Measures of Imagery

Self-report measures of imagery were included to determine the extent that participants' reports about their imagery were related to their performance on the behavioral tasks.

Vividness of Visual Imagery Questionnaire [40]—For each of 16 items on the VVIQ participants were asked to generate and rate the clarity and vividness of visual images (e.g., a sun rising above the horizon) on a 5-point scale ranging from 1 ("perfectly clear and as vivid as normal vision") to 5 ("no image at all, you only 'know' that you are thinking of the object").

Individual Differences Questionnaire [41]—For a subset of 30 of the 86 items in the IDQ (a measure of habitual use of imagery, use of imagery to solve problems, and vividness of daydreams, dreams and imagination), participants indicated on a 5-point Likert scale the extent to which each statement (e.g., "My thinking often consists of mental pictures or images") described their own thinking (1 = very uncharacteristic or untrue, strongly disagree; 5 = very characteristic or true, strongly agree).

Bett's Questionnaire Upon Mental Imagery–Auditory Imagery Scale [42, 43]—For each of the 12 items on the QMI, participants were asked to imagine a sound (e.g., the clink of glasses) and rate the clarity and vividness of each auditory image on a 5-point Likert scale ranging from 1 ("perfectly clear and as vivid as normal hearing") to 5 ("no image at all, you only 'know' that you are thinking of the sound").

Self-Report of Imagery for Behavioral Tasks—A subset of the participants ($N = 52$) were also asked to report on their use of imagery in the specific tasks used in this experiment. For example, for the size comparison task, participants were asked if they used imagery on every trial or only when the size differences were small.

Results and Discussion

Error trials in which participants failed to follow task instructions, did not respond or responded incorrectly, or in which there was experimenter error accounted for 0.5% of the data and were excluded from the analyses. Trial order was unrelated to mean reaction times for all four types of imagery tasks and was not included as a variable in subsequent analyses.

Static Visual Imagery: Animal Size Comparison

Overall, size difference was negatively correlated with mean reaction time, $r = -.64$, $p < .005$ (see Figure 1); when the size difference was small it took longer to decide which animal was bigger. This result is consistent with what we would expect if participants were using imagery. However, as in past research, there were individual differences in the extent that the data from participants showed this correlation pattern. The predicted negative correlation between size difference and reaction time was significant for 26 of the 92 participants (28%) ($p \leq .10$).

Dynamic Visual Imagery: Animal Size Matching

Overall, size difference was positively correlated with mean reaction time, $r = .92$, $p < .001$ (see Figure 2); when the size difference was small, it took less

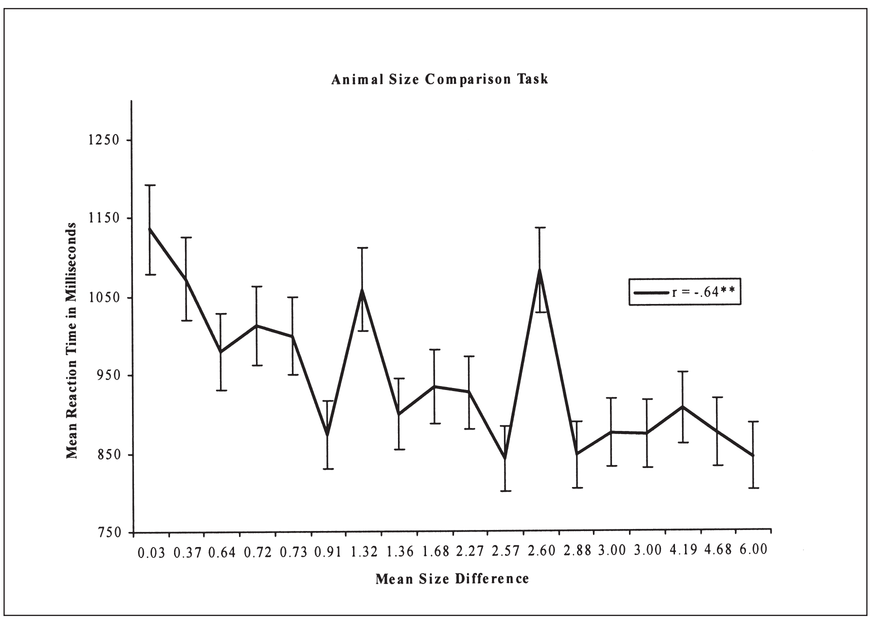

Figure 1. Mean reaction time in milliseconds to decide which animal in the pair is larger in the Animal Size Comparison Task in Experiment 1. The size difference between the animals in each pair increases from left to right on the X axis.

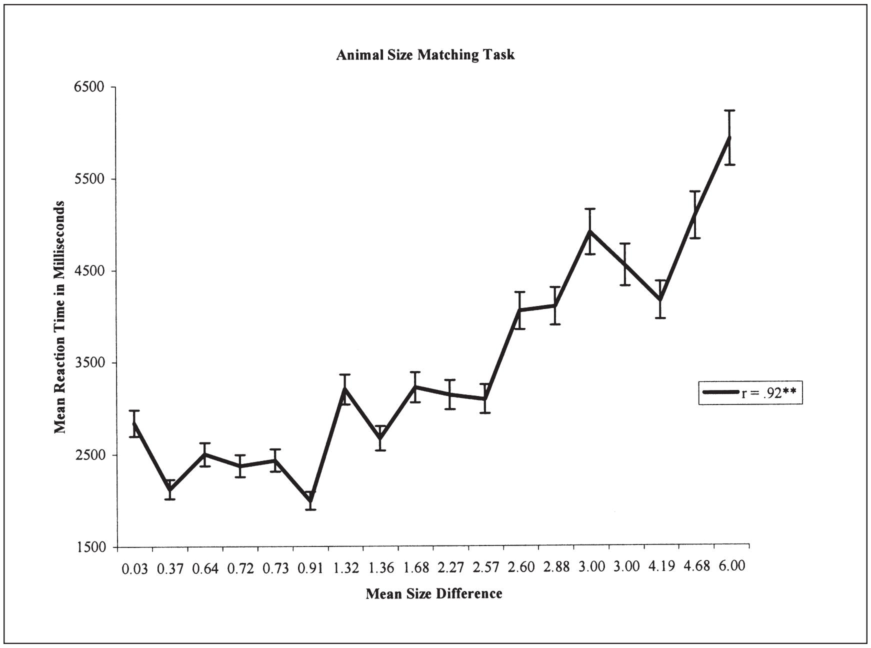

Figure 2. Mean reaction time in milliseconds to make the smaller animal grow to match the size of the larger animal in the Animal Size matching Task in Experiment 1. The size difference between the animals in each pair increases from left to right on the X axis.

time to make one animal grow to the same size as the other. This finding is consistent with what we would expect if participants were using imagery. The predicted positive correlation between size difference and reaction time was significant for 55 of the 92 participants (60%) ($p \leq .10$).

Static Auditory Imagery: Animal Sound Comparison

Overall, volume difference was negatively correlated with mean reaction time, $r = -.64$, $p < .005$ (see Figure 3); when the volume difference was small it took longer to decide which animal sound was louder. This result is consistent with what we would expect if participants were using imagery. The predicted negative correlation between reaction time and volume difference was significant for 31 of the 92 participants (34%) ($p \leq .10$).

Dynamic Auditory Imagery: Animal Sound Matching

Overall, volume difference was positively correlated with mean reaction time, $r = .90$, $p < .001$ (see Figure 4); when the difference in volume was large, it

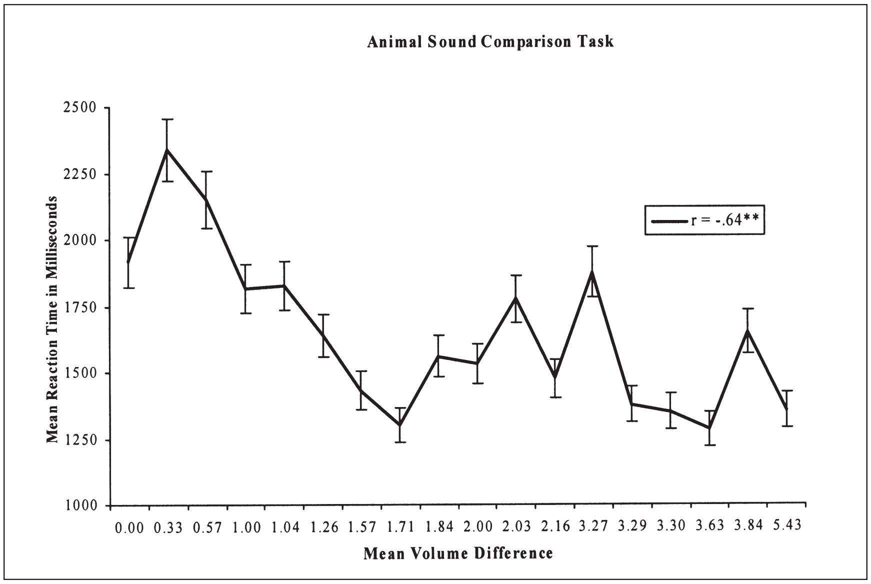

Figure 3. Mean reaction time in milliseconds to decide which animal sound in the pair is louder in the Animal Sound Comparison Task in Experiment 1. The difference in volume between the animal sounds in each pair increases from left to right on the X axis.

took longer for one sound to be "turned up" to match the volume of the second sound. This finding is consistent with the interpretation that participants were using imagery. The predicted positive correlation between reaction time and volume differences, was significant for 56 of the 92 participants (61 %) ($p \leq .10$).

Relationships Among the Imagery Tasks

Each participant's correlation between reaction time and size/volume differences for the four imagery tasks was used as a measure of their imagery use for that task. We used these correlations to assess the extent that imagery use in one type of task was related to imagery use in another (alpha level was set at $p < .008$ for six comparisons). Although the two visual imagery tasks (static and dynamic) showed some degree of relation, $r = -.27$, the correlation did not reach significance. This result is consistent with past research showing little relation between the inspection of visual images and the transformation of them [6]. What is interesting about the present data is that the same pattern was found for auditory imagery. Performance on the static sound comparison task and the dynamic sound matching task were not significantly correlated, $r = -.21$.

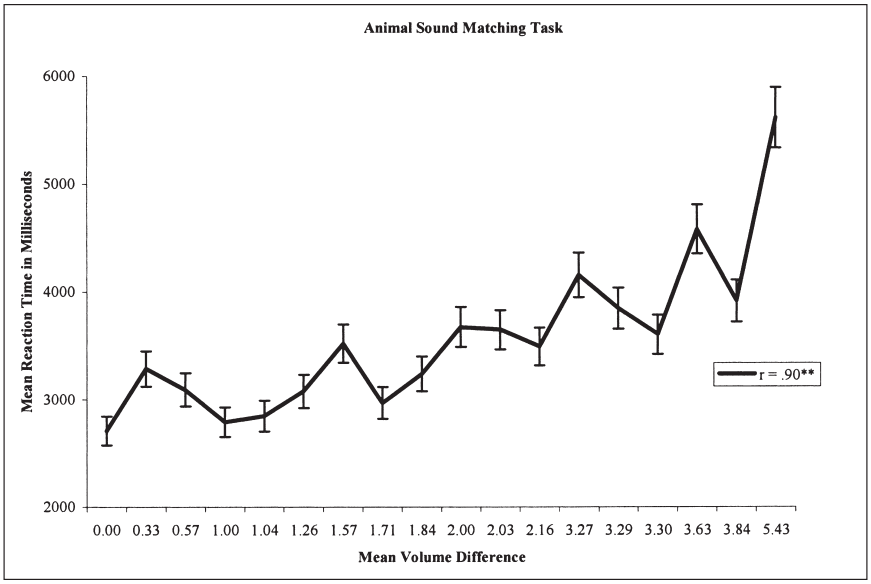

Figure 4. Mean reaction time in milliseconds to mentally increase the volume of the softer animal sound to match the volume of the louder animal sound in the Animal Sound Matching Task in Experiment 1. The difference in volume between the animal sounds in each pair increases from left to right on the X axis.

In contrast, the two static tasks and the two dynamic tasks were both strongly related. There was a positive correlation for performance on the static visual imagery task (Animal Size Comparison) and the static auditory imagery task (Animal Sound Comparison), $r = .37$, $p < .001$. Similarly, there was a positive correlation for performance on the dynamic visual imagery task (Animal Size Matching) and the dynamic auditory imagery task (Animal Sound Matching), $r = .59$, $p < .001$. These cross-modality correlations indicate that the participants showed some consistency in their approach across the session.

Self-Report Measures

The three self-report questionnaires (VVIQ, IDQ, and QMI) all elicited a substantial range in scores and had adequate reliability (Cronbach's alpha = .84, .88, and .85, respectively). In addition, the three questionnaires were all inter-correlated (VVIQ and IDQ, $r = -.43$, $p < .001$; VVIQ and QMI, $r = .61$, $p < .001$; QMI and IDQ scores, $r = -.25$, $p < .02$). However, none of these measures were related to participants' performance on any of the imagery tasks. This result adds to a growing number of studies that have failed to find a relation between self-report and behavioral measures of visual imagery [44-46] and auditory imagery [7, 47].

In addition, for three of the four imagery tasks (size comparison, sound comparison, and sound matching), participants' descriptions of their strategies during the specific tasks used in this experiment did not predict performance. The exception was the dynamic visual imagery task; participants who reported that they formed images of the animals growing ($N = 37$) were more likely to show a correlation between reaction time and animal size difference than participants who reported that the animals were immediately the same size ($N = 14$), $\chi^2(2) = 11.30$, $p < .005$. Overall, however, the evidence indicates that participants' self-reports about imagery vividness and use are not predictive of actual behavioral performance on imagery tasks.

EXPERIMENT 2

The findings from Experiment 1 indicated that our set of imagery tasks was suitable for use with adults to examine individual differences in static and dynamic imagery processes in vision and audition. However, subsequent pilot work showed that our tasks needed to be substantially shortened and simplified to make them appropriate for use with young children. In Experiment 2 we tested a modified set of imagery tasks with a sample of adult participants. The procedure in Experiment 2 was changed from Experiment 1 in the following ways:

a) The number of test trials for each type of imagery was reduced from 18 to 12 because 18 trials per imagery task were too many for the children to complete. To ensure that reducing the number of test trials would not result in insufficient power, we reanalyzed the data from Experiment 1 using only 12 animal pairs and found that the reaction time patterns were virtually identical to the patterns observed with 18 animal pairs.
b) Verbal responses were used instead of mouse clicks because many pilot children either forgot to click the mouse or had difficulty limiting themselves to task-relevant use of the mouse (despite prior practice and reminders during the test trials).
c) In Experiment 1, participants generated images of two new animals on each trial (no animal was presented more than once within two consecutive trials). To reduce potential interference and the memory demands associated with remembering two new animals for each trial, in Experiment 2 participants were presented with a standard animal for each imagery task. For the Animal Size Comparison Task (static visual imagery), participants were asked to compare a series of animals to the size of a cat, and for the Animal Sound Comparison Task (static auditory imagery), participants were asked to compare a series of animal sounds to the sound of a dog barking. For the two dynamic tasks the largest animal (i.e., *elephant*) and loudest animal sound (i.e., *lion roaring*) were chosen as the

standards. Thus, for the Animal Size Matching Task (dynamic visual imagery), participants were asked to mentally increase the size of a series of smaller animals to match the size of an elephant, and for the Animal Sound Matching Task (dynamic auditory imagery), participants were asked to mentally increase the volume of a series of softer animal sounds to match the volume of a lion roaring.

METHOD

Participants

Eighty-three undergraduates (54 females and 29 males; mean age = 20.61 years) completed the modified set of imagery tasks and assisted with stimulus preparation in exchange for course credit. The majority (75%) of the participants self-identified as White ($N = 62$). The sample also included 13 Asians, 1 African American, 1 Latino, 1 Pacific-Islander, and 4 multiracial students.

Development of Stimuli

The stimulus pairs for the Animal Size Comparison (static visual imagery), Animal Sound Comparison (static auditory imagery), and Animal Size Matching (dynamic visual imagery) tasks were constructed using eight of the stimulus animals from Experiment 1 (*pigeon* was dropped because many children were unfamiliar with pigeons) and an additional four animals for which size and volume ratings had been obtained in Experiment 1: *frog, pig, rooster,* and *sheep.* For the Animal Sound Matching Task (dynamic auditory imagery), it was necessary to select an additional animal sound that was relatively loud, but not as loud as a lion roaring. Based on familiarity and mean volume ratings from Experiment 1, *horse neighing* was selected.

Size and volume ratings for the new set of stimulus animals were obtained from the participants and were used in the subsequent analyses (i.e., the size/volume data and reaction times were collected within subjects). The mean size and volume differences for the stimulus pairs used in each of the four imagery tasks are provided in Table 2. For each imagery task, participants received the test trials in one of 12 random orders.

Procedure

First the experimenter asked participants to generate and describe a visual image of a dog and an auditory image of a dog barking. Based on self-reports, all but two participants were able to generate and describe these images. Then participants were given the four imagery tasks. Task instructions and stimuli were presented aloud by the experimenter, and participants provided all of their responses verbally. Reaction times were coded later from audio recordings of the

Table 2. The Mean Size and Volume Differences for Stimuli Used in Experiments 2 and 3

	Mean	*SD*		Mean	*SD*
Size Comparison (cat)			Size Matching (elephant)		
rooster	0.06	0.68	cow	1.40	0.54
duck	0.16	0.51	lion	1.52	0.72
dog	0.89	0.82	sheep	2.60	0.66
pig	0.91	0.84	pig	3.01	0.79
frog	1.15	0.55	dog	3.04	0.69
mouse	1.31	0.56	cat	3.93	0.70
sheep	1.33	0.69	rooster	4.00	0.60
bee	1.95	0.69	duck	4.10	0.60
fly	1.98	0.63	frog	5.08	0.57
lion	2.41	1.14	mouse	5.24	0.60
cow	2.54	0.84	bee	5.88	0.69
elephant	3.93	0.70	fly	5.90	0.58
Sound Comparison (dog barking)			Sound Matching (lion roaring)		
rooster crowing	0.42	1.12	dog barking	1.50	0.95
cow mooing	0.45	1.19	horse neighing	1.74	1.04
sheep baaing	1.25	1.21	rooster crowing	1.90	1.32
elephant trumpeting	1.49	1.26	cow mooing	1.95	0.99
lion roaring	1.50	0.95	sheep baaing	2.72	0.87
pig oinking	1.56	1.18	pig oinking	3.07	0.87
duck quacking	1.82	0.94	duck quacking	3.33	0.90
cat meowing	2.10	1.05	cat meowing	3.60	0.98
frog croaking	2.49	0.92	frog croaking	3.99	1.02
fly buzzing	3.26	1.15	fly buzzing	4.77	1.20
bee buzzing	3.34	1.06	bee buzzing	4.86	1.10
mouse squeaking	3.51	0.92	mouse squeaking	5.01	0.83

session. After completing the imagery tasks, participants rated the size and sound volume of the animals and completed self-report imagery questionnaires.

Static Visual Imagery: Animal Size Comparison [29]—For each of 12 trials, participants were first asked to imagine a cat. The experimenter then asked which animal was bigger, the cat or a new animal (e.g., "Which one is bigger the cat or a sheep?"). When they heard the new animal name, participants imagined the animal, compared it to the cat, and told the experimenter which animal was larger. Reaction time was measured from the presentation of the new animal name to the onset of the participant's verbal response.

Dynamic Visual Imagery: Animal Size Matching—For each of 12 trials, participants were first asked to imagine an elephant. Then the experimenter said the name of a smaller animal (e.g., mouse). Participants imagined the smaller animal growing slowly until it was as large as the elephant and told the experimenter when the two animals were the same size. Reaction times were measured from the onset of the small animal's name to the onset of the participant's verbal response.

Static Auditory Imagery: Animal Sound Comparison (adapted from Intons-Peterson [30])—For each of 12 trials, participants were first asked to imagine the sound of a dog barking. The experimenter then asked which animal sound was louder, the dog barking or a new animal sound (e.g., "Which one is louder, the dog barking or a cow mooing?"). Participants imagined the new sound, compared it to the dog barking, and told the experimenter which animal sound was louder. Reaction time was measured from the presentation of the new animal sound to the onset of the participant's verbal response.

Dynamic Auditory Imagery: Animal Sound Matching (adapted from Intons-Peterson [30])—For each of 12 trials, participants were first asked to imagine the sound of a lion roaring; then the experimenter said the name of a softer animal sound (e.g., bee buzzing). Participants imagined the softer sound, slowly increased the volume of the sound until it was as loud as the lion roaring, and told the experimenter when they had mentally matched the volume of the two sounds. Reaction times were measured from the onset of the name of the softer animal sound to the onset of the participant's verbal response.

Self-Report Measures of Imagery

Given that self-reported imagery vividness was unrelated to task performance in Experiment 1, the assessment was reduced by dropping the VVIQ and QMI. The IDQ, which assesses a broader range of imagery characteristics than the VVIQ or QMI, was retained. Participants also completed a questionnaire regarding the extent that they relied on images to perform the imagery tasks or used alternative strategies (e.g., using images to make comparisons only for small size or volume differences or relying on general knowledge of animal size/sound volume). In addition, participants were asked to complete a questionnaire about childhood imaginary companions, but no differences in performance were found between participants who did and did not recall having a childhood imaginary companion.

Results and Discussion

Error trials in which participants failed to follow task instructions, did not respond or responded incorrectly, or in which there was experimenter error accounted for 2.64% of the data and were excluded from the analyses. The order in which participants completed the imagery tasks did not alter the pattern of results; thus task order was not included as a variable in the subsequent analyses.

Static Visual Imagery: Animal Size Comparison

Overall, size difference was negatively correlated with mean reaction time, $r = -.65$, $p < .02$. However, in contrast to Experiment 1 in which reaction times varied across the 18 stimulus pairs, the reaction times for 10 of the 12 stimulus pairs in this experiment were almost identical. The correlation was driven entirely by the two animal pairs with the smallest differences in size, *cat-rooster* and *cat-duck.* After removing these two pairs, size difference did not predict reaction time. This finding is consistent with past research showing that adults use imagery for size comparisons only when the differences are small [48]. We instructed our participants to use imagery, but it is possible that the use of a standard comparison animal for all of the test trials made this task too simple for adults to use imagery even when instructed to do so. Overall, the predicted negative correlation between size difference and reaction time was significant for only 6 of the 83 participants (7%).

Dynamic Visual Imagery: Animal Size Matching

Overall, size difference was positively correlated with mean reaction time, $r = .94$, $p < .001$. The predicted positive correlation between size difference and reaction time was significant for 43 of the 83 participants (52%).

Static Auditory Imagery: Animal Sound Comparison

Overall, volume difference was negatively correlated with mean reaction time, $r = -.86$, $p < .001$. The predicted negative correlation between sound volume difference and reaction time was significant for 31 of the 83 participants (37%).

Dynamic Auditory Imagery: Animal Sound Matching

Overall, sound volume difference was positively correlated with mean reaction time, $r = .97$, $p < .001$. The predicted positive correlation between sound volume difference and reaction time was significant for 34 of the 83 participants (41%).

Relations Among the Imagery Tasks

Each participant's correlations between reaction time and size/sound volume differences for the four imagery tasks were used to assess the relations among the different types of imagery (alpha level = $p < .008$). However, the interpretation of these analyses was not as straightforward as in Experiment 1 because very few participants appeared to use imagery for the Animal Size Comparison task (static visual imagery). Neither of the correlations involving the static visual imagery task were significant; $r = -.01$, (static visual and dynamic visual imagery) and $r = .01$ (static visual and static auditory imagery). However, if we focus on the inter-task correlations for tasks in which the group means suggested that participants were using imagery (i.e., dynamic visual, static auditory, and dynamic auditory), the pattern of inter-task correlations found in Experiment 1 was replicated; participants' performance on the two auditory tasks was not correlated, $r = -.05$, but performance was significantly correlated across modality for the two dynamic imagery tasks, $r = .44$, $p < .001$.

Self-Report Measures

Scores on the IDQ showed adequate reliability, Cronbach's alpha = .86 (Habitual Use of Imagery = .80; Problem-Solving = .65; and Vividness = .71); however, as in Experiment 1, overall, participants' scores on the IDQ were mostly unrelated to their performance across the set of imagery tasks. The exception was a significant relation between IDQ scores and participants' self-reported task strategies for the Animal Size Comparison Task. Participants who reported inspecting their images on all trials had higher IDQ scores ($M = 120.47$, $SD = 9.47$) than participants who reported inspecting their images only for small differences ($M = 115.61$, $SD = 12.87$) or using semantic knowledge ($M = 106.78$, $SD = 12.92$), $t(78) = 3.19$, $p < .002$. Follow-up contrasts were conducted to determine how self-reported strategies related to specific IDQ factors: participants who reported inspecting their images on all trials had significantly higher scores on the Habitual Use of Imagery factor, $t(78) = 3.37$, $p < .002$.

As in Experiment 1, participants' descriptions of their strategies during the imagery tasks used in this experiment did not predict performance. Thus, whether participants reported using images or an alternative strategy (such as relying on semantic knowledge of size/volume differences in the static comparison tasks or not using images at all in the dynamic tasks) was unrelated to whether they showed the reaction time patterns associated with imagery use on any of the four imagery tasks.

EXPERIMENT 3

In Experiment 3, we gave our four types of imagery tasks (static-visual, dynamic-visual, static-auditory, and dynamic-auditory) to 5-year-old children. We expected that the children would show evidence of using visual imagery for the static-visual task because it was similar to tasks used in past research, but the other three tasks were either new or had not been used with children. Thus, one goal was to determine the extent that children would show the pattern of responses associated with imagery use for these tasks. To the extent that the tasks elicited the patterns of reaction times associated with imagery use, a second goal of this experiment was to determine if children showed any consistency in their use of imagery across task types.

Method

Participants

The initial sample of 100 5-year-old children was reduced to a final sample of 83 children (38 boys and 45 girls; mean age = 5 years 6 months; range = 4 years 11 months to 5 years 11 months) because 17 children chose not to return for the second of the 2 sessions. The children who participated in both sessions ($M = 5.5$, $SD = 3.64$) were significantly older than the children who participated in only the first session ($M = 5.25$, $SD = 3.60$, $t(98) = 2.43$, $p < .05$, $d = .49$). However, the two groups did not differ on gender, ethnicity, or verbal ability. Of the 83 children in the final sample, 72 (87%) were White, 9 (11%) were mixed race, 1 was Asian, and 1 was African American. Children received $10 per session for participation.

Procedure

Each child was tested individually in two 60-minute sessions that were separated by 1 to 3 weeks. In addition to the imagery tasks, the children completed measures of verbal ability (Peabody Picture Vocabulary Test–PPVT-III [49]), waiting ability (NEPSY Statue Test [50]), visual working memory (Mr. Peanut Task [51]), and verbal working memory (Backward Digit-Span [52]). However, none of these measures were related to children's performance on the imagery tasks and will not be discussed further.

Overall, children were asked to complete 48 imagery trials that varied in modality (visual or auditory) and whether they were dynamic or static. Given the number and variety of trials and the demands of the imagery tasks, there were substantial challenges in communicating the different requirements for the tasks to the children and maintaining enough interest for them to comply with the instructions. In pilot research we found that children were more familiar with visual imagery than with auditory imagery and were better able to grasp what we wanted them to do if we started with visual imagery and then moved to auditory imagery. Thus, the visual imagery tasks were presented in Session 1 and the auditory imagery tasks were presented in Session 2. The decision to block the tasks by modality and start with the visual tasks raises the concern that the correlations between imagery tasks presented in the same session might be artificially elevated. However, this possibility works against the predicted cross-modality correlations and provides a more stringent test of the hypothesis that performance on static and dynamic tasks within a modality would not be correlated.

Within each session, the order in which the static or dynamic imagery tasks were presented was counterbalanced; half of the children completed the static tasks first and half completed the dynamic tasks first. Although counterbalancing task order is not recommended for individual differences designs [53], it was important to counterbalance the order in which static and dynamic tasks were presented in this experiment because of the predicted pattern of inter-task correlations. If the two static tasks and the two dynamic tasks turned out to be correlated as predicted (based on the results of Experiment 1), it was important to be able to rule out the possibility that the correlations were due to order effects.

Before presenting the first imagery task in each session, the experimenter asked children to generate and describe an image in the appropriate modality (i.e., a visual image of a dog and an auditory image of a dog barking). The majority of children said they could form visual images (82%) and auditory images (90%) and provided adequate descriptions. Task instructions and stimuli were presented aloud by the experimenter, and the children provided all of their responses verbally. For each imagery task, children completed the test trials in 1 of 12 random orders. The sessions were videotaped, and reaction times were coded later from the audio portion of the videotapes. After completion of the imagery tasks in each session, children were interviewed about the strategies they used to perform the tasks.

Static Visual Imagery: Animal Size Comparison—Children first practiced comparing the sizes of pairs of real objects. The child was shown a rectangular wooden block and asked to remember how big it was. Then the block was removed and the child was shown two different comparison objects, one that was smaller than the block (a paper clip) and one that was larger (a crayon box). For each comparison object the child was asked to compare its size to the target object (e.g., Which one is bigger, the block or the paper clip?). The child was then asked to compare the sizes of imagined objects. After imagining a shoe, the child was asked to imagine a) a marble and b) a couch, and tell the experimenter whether the shoe or the comparison object was bigger.

For each of 12 test trials, children were asked to use visual images to decide whether a cat or another animal named by the experimenter was larger. First the experimenter introduced a hand puppet named Beamer who did not know very much about animals and asked the child to help Beamer learn which animals are bigger than a cat. The experimenter then asked the child to imagine a cat ("Let's think about a cat. Can you see the cat in your head?"). Next the experimenter told the child, "Now I'll say a different animal and ask you to make a picture of it in your head. Look at the picture in your head, and as soon as you know, tell Beamer which animal is bigger, the cat or the new animal." For each trial, the experimenter asked the child, "Which one is bigger, the cat or a ___?" Reaction time was measured from the presentation of the new animal name to the onset of the child's verbal response.

Dynamic Visual Imagery: Animal Size Matching—The experimenter introduced this task by slowly inflating a balloon with an air pump to demonstrate the concept of an image growing slowly. Then the experimenter asked the child to a) imagine a Frisbee, b) imagine a penny, and c) then to make the penny grow slowly in his or her head (like the balloon) until it was as big as the

Frisbee. The child was instructed to start making the penny grow after the experimenter said "Begin" and to say "Okay" as soon as the two imagined objects were the same size.

For each of 12 test trials, the experimenter asked the child to imagine an elephant. Then the experimenter said the name of a smaller animal. Children were instructed to start making the smaller animal grow slowly in their heads once the experimenter said "Begin" and to say "Okay" as soon as the smaller animal was a big as the elephant. Reaction times were measured from the onset of the experimenter's "Begin" to the onset of the child's verbal response.

Static Auditory Imagery: Animal Sound Comparison—Children first practiced comparing the volume of pairs of real sounds. The experimenter played two pairs of sounds on a portable CD-player and asked the child which sound in each pair was louder. The target sound (doorbell) was softer than one comparison sound (car horn) and louder than the other comparison sound (clock ticking). Next the child was asked to compare the volume of imagined sounds. The experimenter asked the child to imagine the sound of a phone ringing and tell her which sound was louder, the phone ringing or a) water dripping, and b) a fire engine siren.

For each of 12 test trials, children were asked to help Beamer learn which animal sounds are louder than a dog barking. First, the experimenter asked the child to imagine the sound of a dog barking. Then the experimenter told the child, "Now, I'll say a different animal sound and ask you to hear it in your head. Listen to the sound in your head, and as soon as you know, tell Beamer which sound is louder, the dog barking or the new sound." For each trial, the experimenter asked, "Which one is louder, the dog barking or a ___?" Reaction time was measured from the presentation of the new animal sound to the onset of the child's verbal response.

Dynamic Auditory Imagery: Animal Sound Matching—The experimenter introduced this task by a) playing the sound of a phone ringing on a portable CD-player, b) playing the sound of a clock ticking, and c) then slowly increasing the volume of the clock ticking while asking the child to tell her when the clock ticking was as loud as the phone ringing. Next the experimenter asked the child to imagine the sound of a) a train whistle and b) soda fizzing, and c) then to imagine slowly turning up the volume of the soda fizzing until it was as loud as a train whistle. (A few children said they did not know what soda fizzing sounded like and were asked to imagine the sound of popcorn popping instead.) The child was instructed to start turning up the sound after the experimenter said "Begin," and to say "Okay" as soon as the soda fizzing was as loud as the train whistle.

For each of 12 test trials, the experimenter asked the child to imagine the sound of a lion roaring. Then the experimenter said the name of a softer animal sound. Children were instructed to start making the softer animal sound slowly get louder in their heads once the experimenter said "Begin" and to say "Okay" as soon as the softer animal sound was as loud as the lion roaring. Reaction times were measured from the onset of the experimenter's "Begin" to the onset of the child's verbal response.

Imagery Task Interviews—Children were interviewed after completing the imagery tasks in each session to obtain more information about their experiences (e.g., how they performed the tasks and the perceived task difficulty), using a format based on the Berkeley Puppet Interview [54]. Children were introduced to two identical dog hand puppets (Iggy and Ziggy), and told that Iggy and Ziggy had played the same imagery games the child just played and would like to talk with him or her about them. For each question, the puppets made opposing statements (e.g., Iggy: "I made a picture of the animals in my head." /Ziggy: "I didn't make a picture of the animals in my head."), and then the child was asked, "How about you?" After administering 4-item interviews to the first 18 participants, the interviews were expanded and the items revised to provide more task-specific information. The expanded interviews were used with the remaining 65 participants. For the static tasks, the items targeted whether the child had used images and whether it was easy or difficult to imagine the animals/animal sounds. For the dynamic tasks, items assessed whether the child was able to make the image transformations (e.g., whether they could see the animals growing in their heads) and whether the image transformations occurred slowly or quickly (e.g., whether the animal sounds got louder "fast" or "slow"). Within each interview, the order in which the puppets spoke and whether the positive or negative statement was presented first alternated across the set of items. The order of which puppet spoke first for each item was also counterbalanced. In addition to the puppet interviews, children were interviewed to determine if they had imaginary companions [55].

Results and Discussion

Imagery Tasks

Error trials in which children failed to follow task instructions, did not respond or responded incorrectly, or in which there was experimenter error accounted for 7.62% of the data and were excluded from the analyses.

Static Visual Imagery: Animal Size Comparison ($N = 83$)—For this task, children showed the predicted negative correlation between size difference and mean reaction time, $r = -.83$, $p < .001$ (see Figure 5). This result replicates the pattern of performance found in Experiment 1 with adults and previous research on mental size comparisons in children [31-33]. The predicted negative correlation between size difference and reaction time was significant for 26 of the 83 children (31%).

Dynamic Visual Imagery: Animal Size Matching ($N = 81$)—Overall, children did not show the pattern associated with the use of imagery. Size difference was

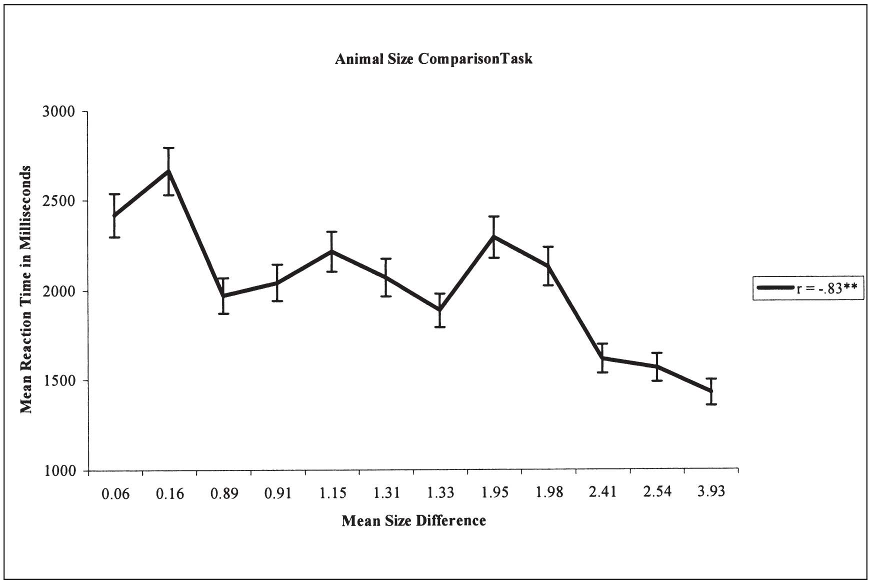

Figure 5. Mean reaction time in milliseconds to decide which animal in the pair is larger in the Animal Size Comparison Task in Experiment 3. The difference between the animals in each pair increases from left to right on the X axis.

not correlated with mean reaction time, $r = .23$, *ns* (see Figure 6). The predicted positive correlation between size difference and reaction time was significant for 9 of the 81 children (11%).

Static Auditory Imagery: Animal Sound Comparison ($N = 83$)—Overall, children did not show the pattern associated with the use of imagery. Sound volume differences were not correlated with mean reaction time, $r = -.39$, *ns* (see Figure 7). The predicted negative correlation between volume difference and reaction time was significant for 5 of the 83 children (6%).

One possible explanation is that children's failure to show the reaction time pattern associated with using imagery for this task was due at least in part to item effects. The selection of *dog barking* as the standard animal sound was based on the familiarity of this sound; however, because dog barking is a relatively loud sound, this produced a disproportionate number of trials in which dog barking was the louder of the two sounds. Item analyses indicated that the two trials in which dog barking was the softer sound (*dog barking-lion roaring* and *dog barking-elephant trumpeting*) had faster reaction times than predicted on the basis of volume difference. Perhaps children did not need to use imagery

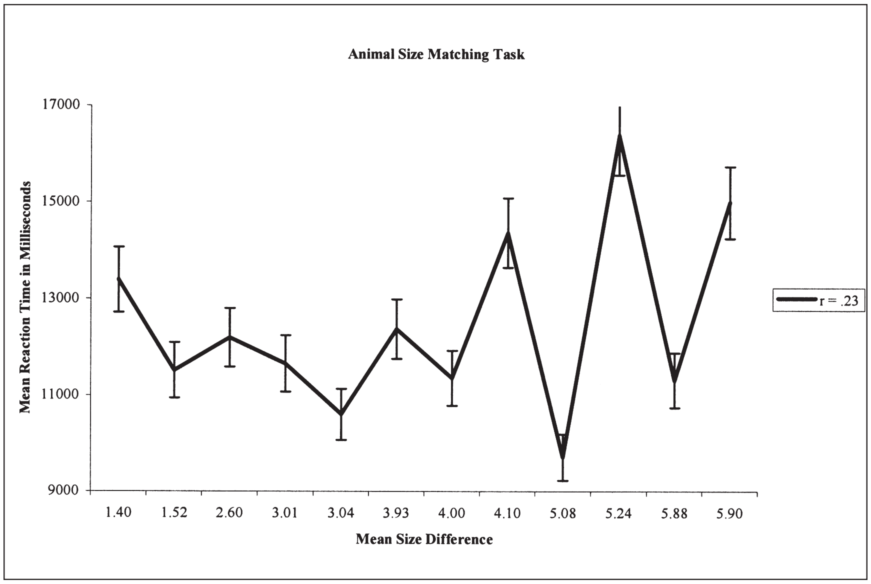

Figure 6. Mean reaction time in milliseconds to make the smaller animal grow to match the size of the larger animal in the Animal Size Matching Task in Experiment 3. The size difference between the animals in each pair increases from left to right on the X axis.

to make these two comparisons because their knowledge about the volume of these two animals was particularly salient. The data provide some support for this interpretation; when *dog barking-lion roaring* and *dog barking-elephant trumpeting* were removed from the regression analysis, there was an overall trend for children to show the predicted reaction time pattern, suggesting that children may have been using imagery only for the pairs in which the dog was the louder animal.

Dynamic Auditory Imagery: Animal Sound Matching ($N = 78$)—For this task, children showed the pattern associated with the use of imagery. Overall, there was a positive correlation between sound volume difference and mean reaction time, $r = .88, p < .001$ (see Figure 8). The predicted positive correlation between volume difference and reaction time was significant for 11 of the 78 children (14%).

Task Order Analyses—Regression analyses were conducted separately for children who completed the static tasks first in each session ($N = 42$) and children who completed the dynamic tasks first ($N = 41$). Children showed the same overall reaction time patterns for the static tasks independent of whether they completed the static tasks first ($N = 42$) or the dynamic tasks first ($N = 41$). For the dynamic

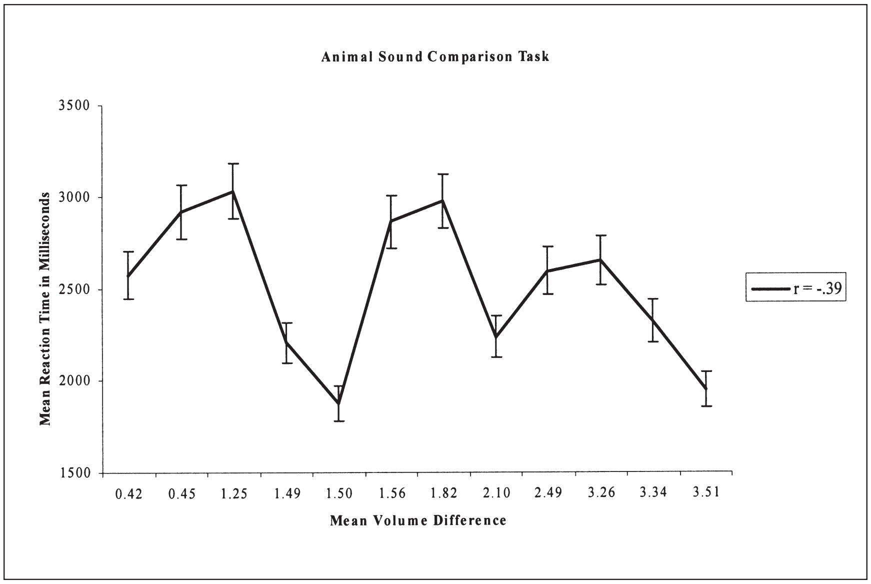

Figure 7. Mean reaction time in milliseconds to decide which animal sound in the pair is louder in the Animal Sound Comparison Task in Experiment 3. The difference in volume between the animal sounds in each pair increases from left to right on the X axis.

imagery tasks, children who completed the corresponding static task first showed better performance (e.g., children who completed the Animal Size Comparison Task first showed better performance on the Animal Size Matching Task). However, these order effects did not alter the pattern of correlations among the set of imagery tasks (i.e., the same pattern emerged for the full sample and for the divided sample).

Relations Among the Imagery Tasks

One goal of this experiment was to determine if children would show the same pattern of inter-task correlations found with the adults in Experiment 1—significant correlations for the two static tasks and the two dynamic tasks, but weak or no correlations for the visual tasks and for the auditory tasks. For the children, three of the four predictions for inter-task correlations were found: static and dynamic visual tasks were not correlated, $r = –.08$, *ns*; static and dynamic auditory tasks were not correlated, $r = .01$, *ns;* but the two dynamic tasks (visual and auditory) were correlated, $r = .36$, $p < .002$. The fourth prediction (a correlation for the two static tasks) was not found, $r = .08$, *ns.* Given that

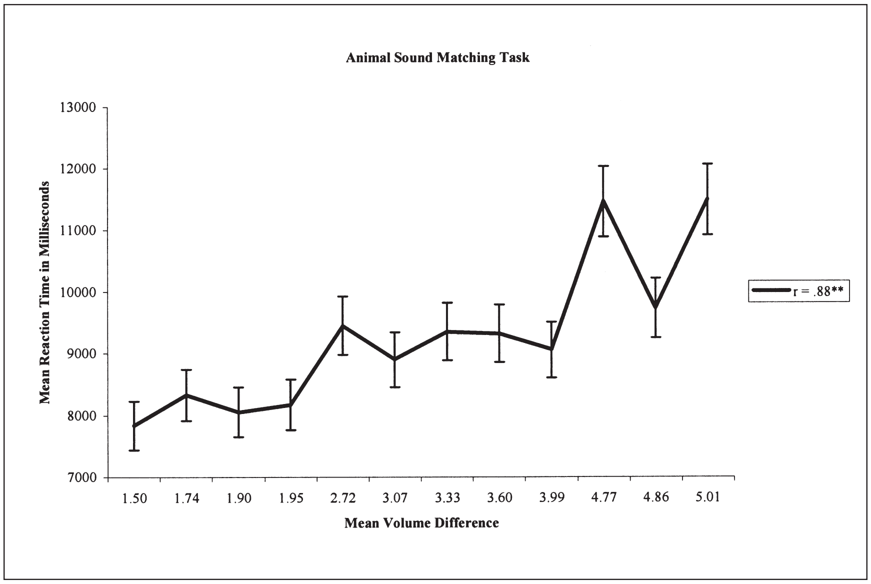

Figure 8. Mean reaction time in milliseconds to mentally increase the volume of the softer animal sound to match the volume of the louder animal sound in the Animal Sound Matching Task in Experiment 3. The difference in volume between the animal sounds in each pair increases from left to right on the X axis.

very few children appeared to consistently use imagery when performing the dynamic visual task and, in particular, the static auditory task, it is not clear how to interpret these results.

Self-Report Imagery Measures

Children's responses were similar whether they received the original set of questions or the expanded revised set; data are presented here only for the children who received the revised version ($N = 65$). Across all four imagery tasks, the majority of the children said that they used images (range: 59-81%) and that it was easy to generate the images (range: 55-75%). Chi-square analyses were conducted separately for each imagery task to compare children who did and did not show the predicted correlation between size/volume difference and reaction time. These analyses indicated that children's self-reports of imagery use were unrelated to their reaction time patterns for any of the imagery tasks. Although most children reported using imagery, few children showed the predicted reaction time patterns across the set of imagery tasks. The lack of association between children's self-reported use of imagery and their task performance is not surprising given the results of Experiments 1 and 2. Like the adults, the children's self-reports of their imagery use during the tasks were unrelated to their task performance.

GENERAL DISCUSSION

The subjective experience of mental imagery is familiar and compelling, but research on this topic presents a variety of methodological and interpretive challenges. Across different types of tasks, there is substantial variation in the extent that one finds the reaction time patterns associated with the use of imagery. Even when such patterns are found, their interpretation as evidence of imagery can be controversial. More generally, whereas some theorists have argued that mental images are central to a range of cognitive processes [48], others have maintained that images are epiphenomenal [56].

However, Kosslyn et al. [4] have recently presented a compelling argument for the functional importance of imagery in cognition. The use of visual imagery can facilitate performance on a range of cognitive tasks involving memory [57], problem-solving [58, 59], skill acquisition [60], and creativity [61]. Across many types of studies, visual images appear to preserve the perceptual and spatial properties of the objects and scenes they represent [62, 63] and the neural bases of visual imagery overlap with the neural mechanisms underlying visual perception [10]. Comparatively less is known about the nature of auditory imagery, but just as visual images contain information about perceived properties such as shape and size, auditory images appear to preserve properties of perceived sounds such as loudness [30] and timbre [9].

Here we present preliminary evidence that individual differences in imagery processes show some consistency across the visual and auditory modalities. In three experiments, we specifically instructed adult and child participants to use mental images; thus, our findings are not informative about the extent that participants use mental imagery *spontaneously* for performing our tasks. However, even though our participants were instructed to use imagery, there was considerable variation in the extent that they showed the reaction time patterns associated with imagery use. Caution is warranted in interpreting the nature of these individual differences, but in all three experiments, the strongest correlations were found across rather than within the visual and auditory modalities. In Experiment 1, the static visual and auditory tasks were correlated and the dynamic visual and auditory tasks were correlated. In contrast, tasks within modalities were only weakly related. In Experiment 2, the static visual task could not be meaningfully used in cross-task comparisons because it did not elicit imagery use; however, we replicated the pattern of correlations for the other tasks (i.e., the visual and auditory dynamic tasks were correlated, but the static and dynamic auditory tasks were not). In Experiment 3 with 5-year-old children, we once again found a correlation in imagery use for the dynamic imagery tasks across visual and auditory modalities (note, however, the limited number of children who used imagery in the dynamic visual task).

One potential concern about this research relates to the nature of the stimuli that participants were asked to image. The advantage of using common animals and animal sounds was that participants could use information stored in memory to generate both the visual and auditory images in the absence of external input. However, the decision to use animals as stimuli without pictorial or auditory supports likely contributed to the variability in reaction times. Specifically, differences in how individual participants typically imagine animals might have added noise to the data (e.g., when asked to form a visual image of a dog, participants could generate an image of a small, medium, or large breed of dog). We tried to reduce this problem by collecting size and sound ratings from the participants, but there was probably still a range in the size or volume of images for particular animals. In addition, participants, especially children, have varying levels of familiarity with animal species. Perhaps research using novel visual and auditory stimuli that are objectively the same for all participants might have some advantages. However, given the large number of stimuli needed for this type of research, the use of novel stimuli would introduce memory demands that would be challenging for adult participants and probably overwhelming for young children.

Another concern—one that is common to behavioral approaches to assessing imagery—is that the data reflect the extent that participants were sensitive to demand characteristics rather than the extent that they used imagery. We believe our data argue against a strong effect of demand characteristics. During the debriefing for Experiment 1 and Experiment 2, participants were asked if they felt that they were expected to respond in a particular way. Of the 156 participants who were asked, only 11 (7%) said they expected that the comparisons or matching would take longer for some pairs relative to others. More generally, the results of all three experiments showed that self-reported imagery vividness and use was uninformative about whether or not participants produced the patterns of responses that are associated with imagery use. The lack of correlation between participants' description of their imagery on the self-report questionnaires and their behavioral evidence of imagery argues against a strong effect of demand characteristics.

Our results for the self-report measures replicate those of other adult studies that have failed to find any relation between self-report and behavioral measures of either visual imagery [44-46] or auditory imagery [7, 47]. The results of Experiment 3 extend this finding to 5-year-old children. Both the dynamic auditory and static visual imagery tasks elicited patterns of performance from the children that reflected the use of imagery, but individual differences in imagery use were not related to children's responses in a puppet interview about imagery. In addition, although children's descriptions of their invisible friends involve visual and auditory images, the children in Experiment 3 who reported having invisible friends were not more likely to use imagery on our tasks than other children. This result suggests that these children's use of imagery does not differ from that of other children. However, there is some research suggesting a dissociation between the neurocognitive processes that underlie the representation of imagined real objects and imagined "unreal" or fantasy objects [64]. Thus, it would be interesting to explore the possibility that children with invisible friends might be particularly likely to show evidence of imagery when asked to scan or manipulate images of fantasy objects rather than the real-life animals used in our experiments.

With a few exceptions [25, 35, 65], most studies that have used behavioral measures of imagery have focused on examining mean performance and have not reported individual differences. In our experiments, adults and young children showed marked individual differences in their approach to the imagery tasks. In Experiments 1 and 2 the dynamic tasks elicited imagery more reliably than the static imagery tasks. The variability in the strategies participants used for the static tasks might have been partly responsible for the lack of correlation for the static and dynamic tasks in both the visual and auditory modalities. However, in Experiment 3, children showed the highest levels of imagery use for the static visual task, and lower levels of imagery use for the other three tasks. Thus, it was not simply the case that all participants used imagery for the dynamic tasks but not the static tasks. Even when adult participants did seem to use imagery for the static visual task (Experiment 1), they did not necessarily use imagery for the dynamic visual task.

The overall differences in mean imagery use for static and dynamic tasks make the lack of correlations within modality less surprising and more difficult to interpret. In contrast, the finding of consistency in imagery use across modality for the two static tasks and for the two dynamic tasks is more interesting. These correlations across modality are striking because there are many differences across the visual and auditory tasks that could have led to different results. For example, in the visual imagery tasks, it was possible and natural to hold images of two animals simultaneously in mind, whereas in the auditory imagery tasks, it was unlikely that participants heard both sounds in the mind's ear at the same time. Instead, the auditory imagery tasks might have involved switching back and forth between images. Despite this difference in the demands of the visual and auditory imagery tasks, the results showed patterns of correlation across imagery modality. Further exploration of the development of imagery processes in vision and audition will advance our understanding of the role that mental imagery plays in human cognition.

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