Temporal differences in eye–hand coordination between children and adults during manual action on objects

Hye Jin Kim ⓘ, Cho Hee Lee ⓘ and Eun Young Kim ⓘ

Abstract

Background/Objective: Eye–hand coordination, which is essential for activities of daily living, develops with age. The objective of this study was to investigate the temporal patterns of visual fixation coupled with hands during manual action on objects in children and young adults.
Methods: Twelve eight-year-old children and 12 young adults performed the Jebsen–Taylor Hand Function Test (JTT) wearing eye-tracking glasses. The interval from the eye arrival time to the hand arrival time on an object was measured as eye–hand arrival span. The interval between the eye departure time and the hand departure time from the object was measured as eye–hand departure span. Eye–hand arrival span, eye–hand departure span and the performance time to complete the JTT were compared between children and young adults. Correlation between eye–hand arrival span and eye–hand departure span was analysed to identify the mechanism of eye–hand coordination.
Results: Compared with young adults, children showed longer performance time but shorter eye–hand arrival span and eye–hand departure span in the JTT. The difference in mean eye–hand arrival span of overall JTT between children and young adults was significant for both hands, whereas differences in the mean eye–hand departure span on the overall JTT and the total performance time were significant for the non-dominant hand. The eye–hand arrival span was positively correlated with the eye–hand departure span.
Conclusion: This study demonstrated temporal differences in eye–hand coordination between children and young adults. Temporal patterns of visual fixation coupled to object manipulation could be useful information about the sensorimotor system in the field of occupational therapy.

Keywords

Eye–hand coordination, eye tracking, Jebsen–Taylor Hand Function Test, occupational therapy, activities of daily living

Introduction

The eyes play an important role in interacting with the environment in our everyday lives. We locate the fovea with the highest resolution in the retina on an object through eye movements and act on the object with information acquired by the eyes (Land, 2006). The coupled movement between the eye and the hand, known as eye–hand coordination, allows us to perform various tasks such as making sandwiches or tea (Hayhoe, Shrivastava, Mruczek, & Pelz, 2003; Land, Mennie, & Rusted, 1999), washing hands (Pelz & Canosa, 2001) and playing sports (Land & McLeod, 2000).

Movements linked to an object include saccading to, grasping, manipulating, releasing the object and so on. During these movements, there is a difference in timing between eye and hand movement. The eyes arrive on an object earlier than the hands (Foulsham, 2015; Land, 2006; Mennie, Hayhoe, & Sullivan, 2007). When washing hands, gaze is directed at a faucet first, and then a hand makes contact with the faucet (Pelz & Canosa, 2001). Similarly, the arrival of gaze on a cup precedes grasping the cup when making tea (Land et al., 1999). Prior eye fixation on an object facilitates motor

Soonchunhyang University, South Korea

Corresponding author:
Eun Young Kim, Department of Occupational Therapy, Soonchunhyang University, Soonchunhyang-ro 22, Asan-si 31538, South Korea.
Email: eykim@sch.ac.kr

planning by locating the object on the central vision with high accuracy (Levi & Klein, 1996).

The extent to which gaze precedes the hand depends on proficiency level on the task. The more participants practice a cup-staking task, the farther their eyes look ahead the place where a cup would be (Foerster, Carbone, Koesling, & Schneider, 2011). Compared with beginners, professional musicians read musical notes far ahead of the notes they are playing (Furneaux & Land, 1999). These previous results demonstrate that experts can look at and manipulate objects faster than non-experts.

The arrival time of the eyes relative to the hand reflects sensorimotor processing (Foerster et al., 2011; Säfström, Johansson, & Flanagan, 2014). If the eyes arrive at an object far before the hand does, the interval between the arrival of the eyes on the object and the contact of the hand on the object will be long. During this interval, proprioception of eye position and visual information about the object can be used to guide hand movement (Abrams, Meyer, & Kornblum, 1990; Säfström et al., 2014). In contrast, if the eyes arrive at an object immediately before the hand does, the interval will be short. In such cases, time might be insufficient to process and transfer sensory information to a motion. The arrival interval between eye and hand could indicate visuo-motor integration, and efficient visuo-motor integration may be reflected by long eye–hand arrival span.

The time when the eyes arrive at an object could be associated with the time when the eyes depart from a previously manipulated object. The eyes not only arrive at objects ahead of the hand but also leave earlier than the hand (Land & Hayhoe, 2001). The eyes often move to the next object soon after a hand grasps the current object in activities of daily living (ADL) even though manipulation of the object is not completed yet. This might be because the somatosensory system rather than the visual system provides sensory feedback. If the somatosensory system is functioning adequately without visual monitoring, the eyes could depart from the object far before the hand; the interval between the eyes leaving the object and the hand leaving the object will be long. In contrast, if reliance on visual monitoring is heavy while manipulating an object, the eyes will have to leave the object immediately before or after the hand; in these cases, the interval between the eyes leaving the object and the hand leaving the object will be short. The departure interval between eye and hand reflects the somatosensory function. Proficient function of the somatosensory system may be reflected by long eye–hand departure span. Long eye–hand departure span would relate to long eye–hand arrival span because the eyes, which depart far ahead of a hand, could arrive at the next object much earlier than the hand, which indicates that the somatosensory system supports the functioning of the visuo-motor system. Therefore, the time interval between eye and hand movements reflects interactions of visual, somatosensory and motor systems.

Taken together, better eye–hand coordination could be characterised by not only shorter performance time but also relatively longer eye–hand arrival span, which could be facilitated by longer eye–hand departure span. This interval property of better eye–hand coordination is inconsistent with that of better bimanual coordination, defined as shorter intervals between hands (Wang et al., 2014; Wu et al., 2009). This discrepancy could be attributed to the fact that the serial relationship between the eye and the hand is different from parallel association between the two hands. In eye–hand coordination, visual information from the eyes is transformed into hand movement in serial order; however, in bimanual coordination, both hands are organised as one unit and processed almost simultaneously.

The pattern of eye–hand coordination in a natural task is similar between children and adults. Children also look at a target before their hands make contact with it (Franchak, Kretch, Soska, & Adolph, 2011). However, the specific aspect of eye–hand coordination differs between children and young adults. Generally, children move more slowly than young adults. In a video game that required a response to select a target upon sudden stimuli, eight-year-old children showed slower eye and hand movements than young adults (Chen & Tsai, 2015). In a reaching task, young adults could reach a target more quickly when they looked at the target than when they did not, whereas infants reached the target at a similar speed regardless of the direction of gaze (Franchak & Yu, 2015). This suggests that infants do not utilise ocular information as much as young adults do when controlling hand movements. These previous studies about eye–hand coordination comparing children and young adults illustrate that the relationship between the eye and the hand becomes more integrated with increasing age. These previous studies that compared eye–hand coordination between children and young adults used a game to touch sudden visual stimuli (Chen & Tsai, 2015) or a one-step task of reaching out to an object (Franchak & Yu, 2015). However, many hand activities in ADL include movements that change the position or state of an object (e.g., transferring a cup) and sequentially manipulate one or more objects (e.g., transferring a cup and then a dish). Temporal characteristics of gaze in children as they perform manual actions with multiple objects in everyday life remain poorly understood.

Thus, the purpose of this study was to investigate eye–hand coordination according to development in structured tasks based on ADL. Specifically, we

examined the differences in temporal patterns of eye–hand coordination between children and young adults using the Jebsen–Taylor Hand Function Test (JTT) (Beagley, Reedman, Sakzewski, & Boyd, 2016; Jebsen, Taylor, Trieschmann, Trotter, & Howard, 1969). During the experiment, children and young adults performed the JTT wearing eye-tracking glasses to record their eye movements. The interval from the time when the eyes started to fixate on an object to the time when a hand contacted the object was measured as eye–hand arrival span. The interval from the time when the eyes departed from the object to the time when the hand separated from the object was measured as eye–hand departure span. Differences in performance time, eye–hand arrival span and eye–hand departure span between children and young adults were analysed. A recent study found that motor coordination impairments are closely related to cognitive abilities and academic achievement in children with neurodevelopmental disabilities (Higashionna et al., 2017). The current study on children's eye and hand movements would provide understanding of eye–hand coordination in performing tasks.

We assumed that the eyes would be efficiently coupled to the hands as a function of the visual–somatosensory–motor system, which contributes to the performance of various tasks. The brain area which integrates visual, somatosensory and motor information is the parietal cortex (Sereno & Huang, 2014). Parietal association areas such as the supramarginal gyrus, which process multisensory information for planning hand action on an object (Tunik, Lo, & Adamovich, 2008), start to mature at the age of 8.5 (Gogtay et al., 2004). Consistent with this finding, children showed a sharp increase of speed in the JTT performance immediately after 8–9 years old followed by a gradual improvement (Jebsen et al., 1969; Taylor, Sand, & Jebsen, 1973). Therefore, 8–9 years old children were selected for the current study because they would have immature visual–somatosensory–motor system and perform the JTT more slowly than young adults. Regarding the temporal pattern of eye–hand coordination, we predicted that children would have shorter eye–hand arrival spans and eye–hand departure spans than young adults.

We also examined whether the time when the eyes arrived at the object was affected by the time when the eyes left the previous object. As the eyes depart from the currently manipulating object earlier than hands, the eyes could reach at the next object earlier than hands. In other words, long eye–hand departure span would be associated with long eye–hand arrival span. In contrast, as the eyes depart from the currently manipulating object shortly before the hands do, the eyes reach at the next object shortly before the hands

do; in other words, short eye–hand departure span would be associated with short eye–hand arrival span. We hypothesised that there was a positive correlation between the eye–hand arrival span and the eye–hand departure span.

Methods

Participants

The participants were 12 children (6 females and 6 males) with a mean age of 8.6 years (range, 8.0–9.5 years) and 12 young adults (6 females and 6 males), who were undergraduate students in the university, with a mean age of 20.8 years (range, 18.7–24.2 years). Participants had normal vision without mental or neurological diagnosis. Apart from 12 children and 12 young adults, one child and three young adults were tested, but they were eliminated from the data analysis because one was ambidextrous, one looked at a pile constantly in a stacking subtest, and two performed the JTT over 2 SD from the mean of time. A cutoff of 2 SD is used to exclude outliers (Miller, 1991; Seo, 2006). This study was approved by our institutional review board (reference number: 201610-SB-037-05).

Procedure

We obtained informed written consent from all participants. To identify the dominant hand in everyday life, participants were asked to complete the Edinburgh Handedness Inventory (Oldfield, 1971). They were also asked to wear eye-tracking glasses to record eye movements without restriction of head movement. After the participants' eyes were calibrated to the eye tracking system, the recording of the eyes and scenes started. While wearing eye-tracking glasses, participants performed the JTT according to a recently published protocol for children (Beagley et al., 2016). The experimental situation is shown in Figure 1.

Instrument

Jebsen–Taylor Hand Function Test. Eye–hand coordination was measured using the JTT (Beagley et al., 2016; Jebsen et al., 1969) to assess functional hand motor skills with objects of daily life. We included in our analyses six of seven JTT subtests related to grasping and releasing. These subtests were simulated page turning, lifting small objects, simulated feedings, stacking, lifting large lightweight objects and lifting large heavy objects. Following standardised instructions, participants were instructed to perform each subtest as quickly as possible.
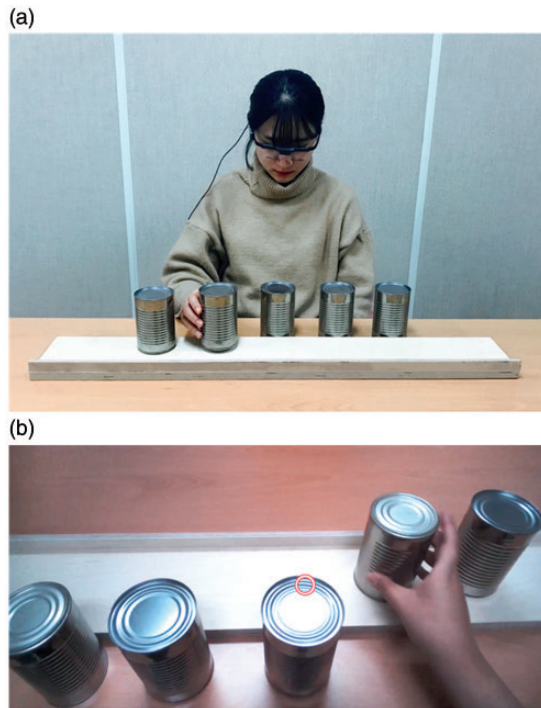
Figure 1. (a) An example of the experimental situation including the JTT and eye-tracking glasses. (b) Eye position indicated by an open circle on the recorded scene.

Eye-tracking glasses. We used Tobii Pro Glasses 2 (Tobii AB, Stockholm, Sweden) to measure the eye movements. These glasses could measure the direction of gaze with one scene camera and four eye-tracking sensors in situations when the head can move freely. Eye position on the scene the participants saw was recorded at a sampling rate of 50 Hz. We inspected the participants' eye and hand movements during the JTT with Tobii Pro Lab. Hand arrival and departure were coded by visual inspection of the video recorded by the eye-tracking glasses, frame (1/50 s) by frame. Eye arrival and departure were coded based on visual fixation, which we identified using the I-V fixation filter of Tobii Pro Lab (Tobii AB, Stockholm, Sweden) with modification for the minimum fixation duration (40 ms).

Data analyses

For each object, we coded the eye arrival time, the eye departure time, the hand arrival time and the hand departure time. We defined the hand arrival time as the time when an object's position began to change due to contact with a hand or tool, and we defined the hand departure time as the time when the hand (or the tool) holding the object began to separate from it. If the eyes fixated on the object at the hand arrival time, we defined the eye arrival time as the starting time of the visual fixation. If the eyes did not direct toward the

object at the hand arrival time, we defined the eye arrival time as the starting time of the visual fixation on the object immediately followed by the hand arrival time. If the eyes fixated on the object at the hand departure time, we defined the eye departure time as the ending time of the visual fixation. If the eyes did not direct the object at the hand departure time, we defined the eye departure time as the ending time of the visual fixation on the object immediately before the hand departure time. For approximately 20% of the checkers on the stacking subtest, we did not code the eye arrival and departure times because participants used near peripheral vision for grasping the checker without moving their eyes from the stacking pile to the checker due to short distance between the pile and checkers.

We calculated the eye–hand arrival span for each object by subtracting the eye arrival time from the hand arrival time; similarly, we calculated the eye–hand departure span for each object by subtracting the eye departure time from the hand departure time. A positive value indicated that the eyes preceded the hand, whereas a negative value indicated that the eyes followed the hand. However, we did not calculate the eye–hand arrival span for the first object in each subtest because participants tended to look at the first object before the start of the JTT. We also did not calculate the eye–hand departure span for the last object in each subtest because there was no specific next object for participants to move their eyes toward. We averaged the eye–hand arrival spans for several objects in one subtest into the eye–hand arrival span for each subtest. Similarly, we averaged eye–hand departure spans for several objects in one subtest into the eye–hand departure span for each subtest.

We further averaged the eye–hand arrival spans from six subtests into a mean eye–hand arrival span for the overall JTT. In the same manner, we calculated the mean eye–hand departure span for the overall JTT by averaging the eye–hand departure spans from the six subtests. We calculated the total JTT performance time by summing the performance times for the six subtests. We measured all variables separately for each hand.

To compare the temporal differences in eye–hand coordination between children and young adults, we analysed performance time, eye–hand arrival span and eye–hand departure span as dependent variables separately by means of single-factor analysis of variance (one-way ANOVA) with age group (children vs. young adults) as the independent variable. First, we analysed total JTT performance time and JTT performance times on each subtest according to age group. Second, we analysed the mean eye–hand arrival span for the overall JTT and the eye–hand arrival spans for each subtest according to age group. Third, we analysed the mean eye–hand departure span for the overall

JTT and the eye–hand departure spans on each subtest as a function of age group.

We performed Pearson's correlation analyses to examine the relationships between eye–hand arrival span and eye–hand departure span. We computed the Pearson's correlation coefficients between the mean eye–hand arrival span for the overall JTT and the mean eye–hand departure span for the overall JTT using SPSS 24.0 (IBM, Armonk, NY). We then calculated the Pearson's correlation coefficients for each subtest between the eye–hand arrival spans and the eye–hand departure spans. We carried out all analyses for each hand (non-dominant and dominant) separately.

Results

Comparison of JTT performance time between children and young adults

There was a significant difference in total JTT performance time for the non-dominant hand between children and young adults, with children needing longer time to perform than young adults (children: 31.64 ± 2.75 s; young adults: 29.04 ± 1.80 s; $p < .05$). For the dominant hand, there was no significant difference in total JTT performance time between children and young adults (children: 28.27 ± 2.30 s; young adults: 26.75 ± 2.47 s; $p = .133$). Results for each subtest are shown in Table 1. Regarding the subtests, the children turned the cards significantly more slowly than did the young adults with the non-dominant hand.

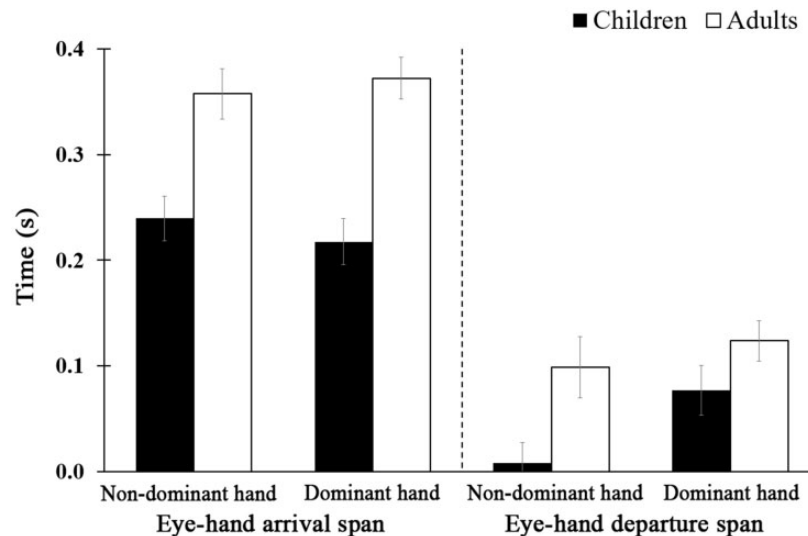### Comparison of eye–hand arrival span between children and young adults

The differences in mean eye–hand arrival span for the overall JTT between children and young adults were significant for both hands (Figure 2). Children showed shorter mean spans for the overall JTT than did young adults for both non-dominant (children: 0.24 ± 0.07 s; young adults: 0.36 ± 0.08 s; $p < .05$) and dominant (children: 0.22 ± 0.08 s; young

Table 1. Comparison of performance time, eye–hand arrival span and eye–hand departure span for each subtest between children and young adults.

Subtest	Hand	Performance time Mean (SD) Children	Adults	F	p	Eye–hand arrival span Mean (SD) Children	Adults	F	p	Eye–hand departure span Mean (SD) Children	Adults	F	p
SPT	ND	4.69 (0.62)	4.07 (0.49)	7.457	.012*	0.20 (0.13)	0.37 (0.18)	6.914	.015*	0.08 (0.30)	0.24 (0.20)	2.293	.145
	D	4.32 (0.64)	3.94 (0.76)	1.799	.194	0.16 (0.20)	0.38 (0.18)	7.744	.011*	0.14 (0.16)	0.24 (0.15)	2.470	.130
LSO	ND	6.27 (0.71)	6.04 (0.53)	0.760	.393	0.23 (0.15)	0.31 (0.07)	2.622	.120	−0.01 (0.10)	−0.02 (0.08)	0.029	.866
	D	6.09 (0.79)	6.01 (1.14)	0.044	.837	0.20 (0.13)	0.30 (0.08)	5.273	.032*	0.07 (0.11)	0.05 (0.11)	0.152	.701
SF	ND	8.45 (0.85)	7.65 (1.13)	3.864	.062	0.39 (0.10)	0.49 (0.12)	4.966	.036*	−0.10 (0.12)	−0.05 (0.11)	1.538	.228
	D	7.19 (0.82)	6.72 (0.91)	1.752	.199	0.37 (0.15)	0.49 (0.18)	3.031	.096	0.01 (0.16)	0.03 (0.15)	0.043	.837
ST	ND	4.51 (1.04)	4.23 (0.72)	0.587	.452	0.15 (0.08)	0.26 (0.10)	8.518	.008**	−0.22 (0.20)	−0.08 (0.12)	4.668	.042*
	D	4.00 (0.73)	3.71 (0.72)	0.921	.348	0.25 (0.09)	0.24 (0.07)	0.047	.830	−0.05 (0.14)	−0.07 (0.12)	0.079	.781
LLO	ND	3.58 (0.63)	3.30 (0.48)	1.464	.239	0.26 (0.12)	0.38 (0.14)	4.974	.036*	0.15 (0.11)	0.20 (0.17)	0.775	.388
	D	3.21 (0.59)	2.97 (0.39)	1.442	.243	0.14 (0.12)	0.43 (0.16)	16.844	.000**	0.12 (0.14)	0.26 (0.15)	6.030	.022*
LHO	ND	4.14 (0.95)	3.74 (0.67)	1.395	.250	0.18 (0.16)	0.34 (0.13)	6.168	.023*	0.18 (0.14)	0.30 (0.19)	2.688	.117
	D	3.46 (0.73)	3.40 (0.49)	0.049	.828	0.14 (0.14)	0.40 (0.15)	17.827	.000**	0.17 (0.12)	0.23 (0.14)	1.327	.262

ND: non-dominant hand; D: dominant hand; SPT: simulated page turning; LSO: lifting small objects; SF: simulated feedings; ST: stacking; LLO: lifting large lightweight objects; LHO: lifting large heavy objects.
*$p < .05$; **$p < .01$.

Figure 2. Comparison of mean eye–hand arrival span and mean eye–hand departure span for the overall JTT between children and young adults. Error bars represent standard errors.

adults: 0.37 ± 0.07 s; $p < .01$) hands. For both hands, the children's eye–hand arrival spans were significantly shorter than those of the young adults in subtests of simulated page turning, lifting large lightweight objects and lifting large heavy objects (Table 1). Children also showed significantly shorter eye–hand arrival spans than the young adults did in simulated feeding and stacking with the non-dominant hand and in lifting small objects with the dominant hand.

Comparison of eye–hand departure span between children and young adults

The difference in mean eye–hand departure span on the overall JTT between children and young adults was significant in the non-dominant hand (Figure 2), with children showing shorter mean span on the overall JTT than did young adults (children: 0.01 ± 0.07 s; young adults: 0.10 ± 0.10 s; $p < .05$). For the dominant hand, there was no significant difference in the mean eye–hand departure span on the overall JTT between children and young adults (children: 0.08 ± 0.08 s; young adults: 0.12 ± 0.07 s; $p = .137$). On the subtests, the children's eye–hand departure spans were significantly shorter than those of the young adults in stacking with the non-dominant hand and in lifting large lightweight objects with the dominant hand (Table 1).

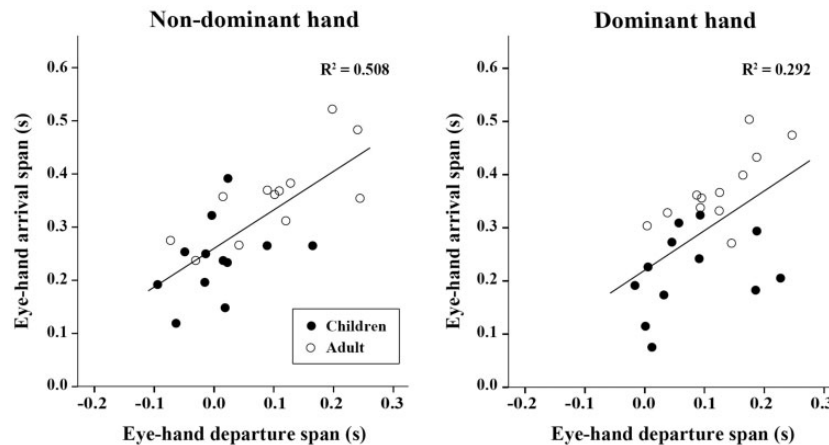### Correlation between eye–hand arrival span and eye–hand departure span

We found significant positive correlations between the mean eye–hand arrival spans and the mean eye–hand departure spans on the overall JTT for both the

non-dominant ($r = .713$, $p < .01$) and dominant ($r = .540$, $p < .01$; Figure 3) hands. On the subtests, eye–hand arrival spans correlated positively with eye–hand departure spans in simulated page turning, stacking and lifting large lightweight objects tasks for both hands (Table 2). There were also significant positive correlations between eye–hand arrival spans and eye–hand departure spans in lifting small object with the non-dominant hand and lifting large heavyweight objects with the dominant hand.

Discussion

In this study, we investigated temporal differences in eye–hand coordination between children and young adults during manual action on objects; the participants performed the JTT while wearing eye-tracking glasses. The children showed longer performance time but shorter eye–hand arrival and eye–hand departure spans than did the young adults. This result means that children were less efficient than young adults in eye–hand coordination. The positive relationship between eye–hand arrival span and eye–hand departure span demonstrates that the eyes leaving an object much earlier than a hand could arrive at the next object much more quickly than the hand, which suggests that somatosensory function supports visuo-motor integration.

This study provides additional evidence for prior eye fixation on objects in both children and adults. Consistent with previous findings (e.g., Franchak & Yu, 2015; Land et al., 1999), children and adults looked at an object before making contact with it

Figure 3. Correlation analyses between mean eye–hand arrival span and mean eye–hand departure span for the overall JTT.

Table 2. Correlation between eye–hand arrival span and eye–hand departure span for each subtest.

Subtest	Hand	R	p
SPT	ND	.651	.001**
	D	.593	.002**
LSO	ND	.558	.005**
	D	.364	.080
SF	ND	.257	.225
	D	.369	.076
ST	ND	.552	.005**
	D	.442	.040*
LLO	ND	.729	.000**
	D	.869	.000**
LHO	ND	.411	.064
	D	.716	.000**

ND: non-dominant hand; D: dominant hand; SPT: simulated page turning; LSO: lifting small objects; SF: simulated feedings; ST: stacking; LLO: lifting large lightweight objects; LHO: lifting large heavy objects.
$*p < .05$; $**p < .01$.

with their hands. Furthermore, the current study revealed that children showed shorter eye–hand arrival span than did young adults. This suggests that, compared with young adults, children have less time processing information acquired from the eyes to plan and execute hand movements. In other words, the interaction between the visual system and the motor system to support optimal performance is not fully developed in children at the age of eight.

Children also showed shorter eye–hand departure span than did the young adults; the difference in eye–hand departure span for the overall JTT between the children and the young adults was significant for the non-dominant hand. The children looked at an object until just before their hand completed object manipulation, whereas young adults looked at the object long before they finished the manipulation. This result

suggests that children are more dependent on visual input than young adults, presumably due to their less developed somatosensory system (Zanini, Martucci, Del Piero, & Restuccia, 2016). Children's heavy reliance on visual monitoring was more pronounced for the non-dominant hand. From this result, we infer that children have less developed somatosensory function than young adults when performing the task with the non-dominant hand.

Throughout the tasks, the eyes arrived at the object before the hand made contact with the object. In contrast, depending on the task, the eyes left the object at different times in relation to the time the hand separated from the object. When the object was released to a large place such as a board or a desk (simulated page turning, lifting large lightweight objects, and lifting large heavy objects), eye–hand departure spans were positive, indicating that the eyes left the object before the hand did. On the other hand, when the object was released to a small target such as a can or a checker (lifting small objects, simulated feedings and stacking), eye–hand departure spans were close to zero or even negative, indicating that the eyes left the object just before or after the hand did; participants moved their eyes to the next object after the previous object was within the small target. This result is consistent with previous studies (Johansson, Westling, Bäckström, & Flanagan, 2001; Land et al., 1999) showing that participants hold their gaze on a small target to guide an object.

If the eyes remained on the object to monitor events, the eyes could not direct toward the next object early. As the participants performed a series of manual actions on objects, the time when their eyes left the object could affect the time when their eyes arrived at the next object. This relationship was demonstrated by the positive correlations between eye–hand arrival spans and eye–hand departure spans. This result

implies that visual, somatosensory and motor systems are interrelated during action. To separate the eyes from the manipulated object early, the somatosensory system needs to be sufficiently developed to process events related to the object without visual input (Land & Hayhoe, 2001). Untied eyes can move freely to the next object, which facilitates motor planning (Abrams et al., 1990; Säfström et al., 2014).

As expected, children showed longer total performance time than did young adults. There was statistically significant difference in total performance time between children and young adults only for the non-dominant hand. However, children and young adults performed the JTT at similar time with the dominant hand. This might be because the dominant hand develops more rapidly than the non-dominant hand (Bryden & Roy, 2005). It is also possible that the number of participants in this study was not sufficiently large to find statistical difference for the dominant hand.

Temporal measurement in this study could provide occupational therapists with rich information about performance of eye–hand coordination between children and young adults. On several subtests (e.g., lifting large lightweight objects), there were differences between the children and young adults in the eye–hand arrival time but not in the performance time. This result indicates that the eye–hand arrival time could be a sensitive measure for detecting differences in eye–hand coordination. The eye–hand departure span reflects somatosensory function because hand manipulation of an object relies on the tactile and proprioceptive senses during this span. This implies that the eye–hand departure span may be an objective indicator of somatosensory processing. The relationship between eye–hand arrival span and eye–hand departure span indicates that the visuo-motor system may be connected to the somatosensory system. Occupational therapists need to consider further evaluation of somatosensory function during eye–hand coordination training.

This study has several limitations. First, the sample size was relatively small, although we found meaningful results related to eye–hand coordination measured by eye-tracking glasses. Further study with more subjects in various age ranges is needed for systematic analysis to obtain implications about developmental trajectory. Second, participants were not diagnosed with disorders that affect eye–hand coordination. Thus, this study has indirect implications for clinical practice with eye–hand coordination problems. Further study is needed to explore temporal characteristics according to disorders (e.g., cerebral palsy and developmental coordination disorder) using the paradigm of this study. Third, hand events were measured frame by frame with visual inspection. Sensors to detect hand motion could be introduced for more objective measurement in future studies. Fourth, eye–hand coordination values were not validated with other measurement instruments such as the Beery–Buktenica Developmental Test of Visual-Motor Integration (Beery, Buktenica, & Beery, 2010). The issue of converging evidence could also be researched in the future.

Conclusion

This study demonstrated that eye–hand coordination during the JTT differed between children and young adults. Compared with young adults, children showed shorter eye–hand arrival span and eye–hand departure span but longer performance time. The difference in eye–hand coordination between children and young adults by eye–tracking implied that visual–somatosensory–motor processing was not fully developed in children at age eight. This study could be used as a basis to investigate the mechanism of eye–hand coordination for various disorders. Temporal patterns of eye–hand coordination could provide occupational therapists with information about the sensorimotor system.

ORCID iD

Hye Jin Kim http://orcid.org/0000-0001-8480-6789
Cho Hee Lee http://orcid.org/0000-0001-9206-8894
Eun Young Kim http://orcid.org/0000-0002-6882-2954

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