DEVELOPMENT OF CHOPSTICK USE BY CHINESE CHILDREN

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Introduction

Eating with utensils is a form of tool use that emerges early in human development. Eating involves the coordination of both spatial and motor abilities to transport food and is shaped by social and cultural contexts. In contrast to young Western children, however, Chinese children have to learn to control and manipulate chopsticks for eating. The use of chopsticks also requires intricate coordination between hand and fingers, including movements of the fingers in relation to one another and in relation to the palm. This differs from the use of western utensils which involves the use of both hands and primarily movement of hand and arms. Despite considerable research into the development of utensil use (e.g., spoon) by Western children (Connolly & Dalgleish, 1989), the development of chopstick use by Asian children remains understudied. Most existing studies on chopstick use have also focused on well-controlled tasks in lab settings. Little research has examined how young children learn to eat with chopsticks in natural contexts. This study aims to address the gap by investigating how Asian, particularly Chinese, children learn to use chopsticks for eating in their homes.

Chopstick and Utensil Use

Eating with utensils, one form of tool use, has been well-documented in the literatures (e.g., Fowler, 1947; Moorehead, 1910; Wright, 2000). Throughout history, humans have adaptively developed, used, and modified utensils to achieve goals that cannot be accomplished by hands alone. In the Early Stone Age, early humans started utilizing hammerstones as an early utensil to access food by cutting fruits and pounding or crushing meat from animals (Sillitoe & Hardy, 2003). For more advanced use, humans have developed and used modern utensils (e.g., spoons and chopsticks) to prepare, transport, and consume food. For example, as early as 1200 BCE, chopsticks were developed from twigs to retrieve food from cooking pots in ancient China (Lu, 2004). Over time, chopsticks evolved from cooking tools to a means of cutting food into small pieces to conserve fuel. Today, chopsticks are used globally by nearly a third of the world's population to grasp food from bowls or plates (Wang, 2005).

Eating with chopsticks involves coordinating spatial cognitive and motor abilities (Wong et al., 2002). Before each attempt to reach for food, individuals need to spatially align and orient the chopsticks ends. The ends of the chopsticks are matched up and the tapered ends are oriented towards the food. Similar to the use of other utensils (e.g., spoons), individuals should then ensure the tapered ends of chopsticks are touching the food by coordinating the spatial cognitive processing to locate the food with their motor movements (Acharda & von Hofsten, 2002). They should pinch and then carry the food to the mouth successfully without losing the contents while manipulating the chopsticks. Subsequently, they are supposed to empty the chopsticks and extract them from the mouth. All these processes in eating with chopsticks require spatial cognitive and motor coordination.

The manipulation of chopsticks for eating also requires coordination between the dominant hand and fingers. This differs from other utensil use which primarily involves movement of the hand and arms. The use of chopsticks requires skillful movements of the fingers, particularly the thumb, index, and middle fingers (Sandra et al., 2002; Don and Joseph, 1954). The fingers must be able to move in relation to one another and apply force to the chopsticks by holding the handles. The palm also supports the chopstick handles through coordination with the finger movements. In this case, people flexibly employ the grip strategies—the way people coordinate the movements of fingers and the hands in relation to the chopsticks—to pinch different shapes and properties of foods and then transport them from the serving dishes to the mouth without drops. In contrast, using other utensils, such as spoons, primarily involves hand and arm movements, such as wrist rotation, elbow flexion and shoulder flexion (Connolly & Dalgleish, 1989).

In order to better describe the way people manipulate chopsticks, Lin, Dong, Sun and von Hofsten (2001) introduced eight major grip modes adopted by both Chinese children aged 3-7 years and Chinese adults. The modes were classified based on the relative positions of the fingers to one another and each chopstick. Table 1 shows the grip modes with descriptions and an example of each mode (Lin, Dong, Sun, & von Hofsten, 2001). The first two modes are classified as adult grips, while the remaining six modes are classified as child grips. Adults and older children aged 7 years tended to use the adult grips compared to the younger children aged 3 years. Conversely, the younger children were more likely to use child grips as opposed to the adults and the older children. These, at least in part, suggested the developmental characteristics in the acquisition of the skill of chopstick use. However, people may wonder how exactly children develop such skill. How do they develop the motor ability to control the movements of the fingers and the hand for chopstick use and coordinate the motor ability with their spatial cognitive ability during development? In the subsequent section, we will review literature that explores the development of utensil usage in children and its connection to chopstick use.

Table 1. Eight grip modes by 3-to-6-years old Chinese children and adults and an example of each mode.

Grip mode	Descriptions	Examples
1	Thumb and ring fingers holding one chopstick; index, middle and thumb holding the other.	
2	Thumb and pinky fingers holding one chopstick; middle, ring, and thumb fingers holding the other.	
3	Middle, ring, and thumb fingers holding one chopstick; index and thumb fingers holding the other.	
4	Thumb, index, and middle fingers controlling chopsticks; index resting on both chopsticks; ring and pinky fingers never touching chopsticks.	
5	Thumb and index fingers controlling chopsticks; middle, ring, and pinky never touching chopsticks.	
6	All fingers touching or controlling chopsticks.	
7	Middle, ring, and thumb fingers holding one chopstick; index and thumb holding the other.	
8	Thumb, index, and middle fingers controlling chopsticks. This grip is similar to the fourth grip except that all fingers are outstretched in this grip.	

Development of Spoon Use and Chopstick Use

The acquisition of the ability to use utensils for eating is one of the critical developmental milestones in the first few years of human life. In the second half of children’s first year, spoons are introduced to most children as their first tool. Children are fed by caregivers at this age. Over time, children gradually develop independence and competence in using the spoon, before moving on to other advanced utensils such as a fork and a knife. Social interaction, particularly between caregivers and children, significantly impacts and shapes this learning process.

Studies have shown that the development of spoon use occurs in a continuous fashion. During the first year of life, children typically learn the skill by observing the caregiver’s use of the spoon. The caregiver's role in providing opportunities and controlling the learning environment is crucial in the learning process. For instance, young children initially watch the spoon and alternate their gaze between the dish and the spoon (Gesell & Ilg, 1937). After a few trials of feeding by caregivers, young children could anticipate the spoon’s arrival by opening their mouths prior to the spoon touching their lips. This suggests that children are getting better at understanding the purpose of retrieving food from a dish with a spoon and the self-spoon-eating relationship as they are watching caregivers feeding them with a spoon.

During the second year, children gradually develop competence and independence in using a spoon for eating (Connolly & Dalgleish, 1989; Nonaka & Goldfield, 2018; Nonaka, T. & Stoffregen, T. A., 2020). The transition from the use of the hand to a spoon is continuous (Itaguchi & Fukuzawa, 2014), with children sometimes using both hand and spoon simultaneously. For example, researchers reported that, in the early phase, young children hold the spoon and put it into and out of the dish repeatedly with one hand while using the other hand to retrieve food from the dish and feed themselves (Gesell & Ilg, 1937). They may also start the learning by exploring a spoon itself by banging, throwing, and eating and different ways to grasp a spoon. At younger age, children tend to hold the spoon in some rigid ways that prevent the movements within the hand (Connolly & Dalgleish, 1989). As they become older, children less frequently use their bare hands and exhibit lower variability in ways of holding a spoon. They tend to use more consistent but efficient strategies to manipulate a spoon. The more mature strategies allow more flexible movements of the hand and wrists while scooping food from a dish and transporting it to the mouth without drops. Caregivers play an important role in supporting the learning process, such as adjusting the spoon's placement and food layout during meals to facilitate the appropriate use of the spoon (e.g., Nonaka & Goldfield, 2018). As caregivers and children do so, caregiver involvement decreases. Children are gaining independence in manipulating the spoon and competence in employing efficient strategies in eating with a spoon.

Other than using a spoon, Chinese children have to learn to use chopsticks for eating. Similar to spoon use, Chinese children typically start by observing adults or their older siblings using chopsticks during meals at home. They are becoming familiar with chopsticks and acquiring some knowledge about the chopsticks through daily repeated exposures. At an older age, they are given chopsticks and can explore the use of chopsticks. For example, Lin, Dong, Sun, and von Hofsten (2001) studied how Chinese children develop to coordinate their hand and fingers for picking up and moving wooden objects with chopsticks. They discovered that the novice chopstick learners were more likely to use immature rigid grips (i.e., clutch) that limited hand and finger movements (Lin, Dong, Sun, & von Hofsten, 2001). Adults and 7-year-olds were more likely to adopt adult grips than 3-year-olds. However, this study took place in a laboratory setting and the participants were asked to complete a specific task. There is limited research on the development of chopstick use skills in natural settings such as during mealtimes at the participants' homes.

Functional Development of Chopstick Use for Eating

As previously discussed, existing research on tool use, specifically chopstick use, has primarily centered around the formal structure of gripping gestures in the course of development. These studies often involved instructing participants to use their most commonly used grip strategy while picking up a wooden object and transporting it with chopsticks (Lin, Dong, Sun, & von Hofsten, 2001). Given the task demands and the solid-wooden texture of objects, the children were expected to use the grip strategies as consistently as possible. At a younger age, children were more prone to adopting immature and inflexible grips to manipulate chopsticks due to the limitations imposed by their fingers and hands. However, as the muscles in their fingers and hand mature, children gradually acquire greater strength and dexterity, enabling them to perform more sophisticated and complex manual actions with chopsticks. Consequently, participants tended to use more mature ways of manipulating chopsticks as they aged.

Despite these findings, the functional development of chopstick use has been overlooked in these studies. Firstly, younger children may not readily be able to transport an object along a continuous path. They might drop the object in the middle of holding or moving it. It is also possible that they might pick it up again and/or change the grip strategy to accomplish the task. Such occasions were ignored in the previous studies. Additionally, in real-life eating situations, the texture of food items can vary, leading individuals to adopt different strategies for picking up and transporting different foods (e.g., rice, leafy vegetables, and meat chunks) to their mouth. This may involve modifying grip strategies and adapting to different food textures. Research examining the development of tool use—chopstick use—in a natural ecology remains limited and has not examined the functional components of the acquisition of chopstick use skill. This study thus aimed to address these research gaps.

Current study

The purpose of the present study was to investigate the natural developmental trajectory of chopstick use and to address gaps in the existing research. Three primary questions were explored. The first question was concerned with the formal development of chopstick use. Specifically, we measured the grip strategies used by the participants, in which we were attempting to replicate previous research findings and examine whether older children were more prone to use adult grip strategies to manipulate chopsticks even in natural eating contexts. The second question pertained to the functional development of chopstick use. To this end, we measured the frequencies and proportions of self-feeding and dropping occasions, testing for changes with respect to the age of the children. Additionally, we measured the frequency and proportion of independent self-feeding occasions without caregiver involvement, investigating whether it also varied with age. Finally, we investigated the relationship between the functional and formal structure of chopstick use throughout development. For example, we tested whether the change in the use of grip strategies would correlate with the change in the frequency and proportion of self-feeding, dropping, and independent-feeding occasions with age.

It should be noted that the present study exclusively focused on the development of chopstick use by Chinese children. Although most Asian people use chopsticks as their primary utensil for eating, Chinese people may not use chopsticks in exactly the same ways as their Japanese and Korean counterparts. In particular, Chinese chopsticks tend to have rounded ends, while Korean and Japanese chopsticks typically have thin, pointed ends. As such, there may be differences in the strategies employed by Chinese children when manipulating chopsticks, as compared to children from other cultures.

In line with previous research, we hypothesized that children would increasingly adopt more mature adult grips and reduce their use of less mature child grips in natural contexts as they grow older. Additionally, we expected functional components to develop with age, leading to more engagement in self-feeding and independent-feeding, and less engagement in dropping events. Lastly, we hypothesized that a significant correlation between the formal and functional development of chopstick use in Chinese children.

Method

Participants

Participants in the current study were 48 Chinese children (31 girls) aged 21-78 months (mean age=49.2 mos., sd=15.6) and their families who were recruited from local community in Guiyang, China. All children had normal vision and hearing and were developing typically. Five children (at the age of 25, 27, 28, 34, and 39 months) never used the chopsticks because either they were unable to manipulate chopsticks or their caregivers never gave them chopsticks. Three (at the age of 42, 42, and 56 months) children had fewer than 5 total events coded because they used a spoon for most for their mealtime. Two children (at the age of 31 and 36 months) used trainer's chopsticks during the entire mealtime. Thus, we had 38 children (25 girls) for subsequent analyses (mean age=52.6 mos., sd=15.1; see Figure 1). Written informed consent was obtained from parents or legal guardians of all participants prior to their involvement in the study.

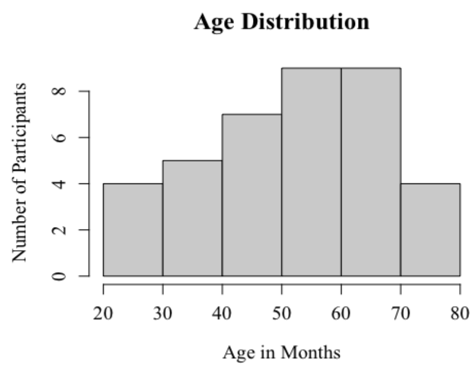

Figure 1. Age distribution of participants included in subsequent analyses.

Procedure

We adopted a naturalistic observation approach to investigate the development of chopstick use during mealtimes in their homes. Mealtimes typically lasted 10-50 minutes. Children were instructed to feed themselves as they would. Caregivers were instructed to interact normally with their children. A research assistant recorded the movements made by children and their caregivers with a handheld camera. After the recording session, the caregiver completed a demographic questionnaire. The demographic questionnaire collected information on the child's age and gender.

Data Coding

Two trained research assistants independently coded the videos using the *Datavyu* software (www.datavyu.org). A coding scheme was developed specifically to measure the formal and functional structure of chopstick use by each participant. The coding scheme comprised the three main categories: (1) type of event, (2) caregiver physical involvement, (3) grip strategies used. The formal structure was evaluated by assessing the grip strategies used, while the functional development was determined by quantifying the first two coding categories (i.e., type of event and caregiver physical involvement). Three types of events, feeding, serving, and dropping, were coded for each video clip. A feeding event was defined as starting from touching the food through the food touching the children's mouth by chopstick. A serving event referred to transporting the food from the serving plate to the children's personal bowl, and a dropping event involved food drops while children were attempting to serve or feed themselves. As for caregiver physical involvement, we used binary coding to indicate whether the caregiver ever physically touched the chopsticks or the child's hand or arm during each feeding, serving, or dropping event. It is important to note that our focus in this study was primarily on the physical involvement of caregivers during the child's self-feeding, serving, or dropping occasions, which included instances where caregivers held the child's hand to grasp the chopsticks. Caregivers demonstrating how to use chopsticks by using their own chopsticks without touching the child's chopsticks was not considered as a caregiver-involved event. Grip strategies were coded as one of the Grip Modes 1-8, referencing Lin et al.'s (2001) classification for grips, which considers the position of the hand and each finger in relation to each chopstick.

Coders watched each video and identified instances of each category using *Datavyu*. The inter-coder reliability was assessed using Pearson Correlation Coefficient for the events and Cohen's Kappa for the grip strategies and high values were obtained ($r = .94$-$.96$, *p*s $< .001$; $\kappa = .99$, $p < .001$).

Table 2. Inter-coded Reliability.

Variable	Coefficient	p-value
Number of total events	r = .95	<.001
Number of self-feeding events	r = .95	<.001
Number of independent events	r = .94	<.001
Number of serving events	r = .96	<.001
Number of dropping events	r = .95	<.001
Grip modes 1-8	κ = .99	<.001

Data Analysis

We used R software to conduct data analysis. Specifically, the coded data was imported into R and subjected to a series of statistical analyses aimed at addressing the three questions mentioned in the introduction section. The first set of analyses focused on the formal structure of chopstick use by the children. As previously discussed (Lin, Dong, Sun, & von Hofsten, 2001), the formal structure of chopstick use includes eight modes that are classified based on the relative position between fingers and chopsticks (Table 1). Among these modes, Mode 1 and 2 are considered adult grips. The remaining six modes are classified as child grips. This study investigated the use of adult versus child grip strategies and also examined the use of separate child grips. Several generalized linear models (GLMs) were run in R with the lme4 package, with the frequency of grip strategies (i.e., adult grips, child grips, and separate child grip modes) as dependent variables and age as an independent variable. Additionally, simple linear regressions were conducted in R, with the proportions of grip strategies as dependent variables and age as an independent variable. Considering that we had repeated measures nested within each individual, we also employed generalized linear models (GLMMs) in R with a logit link. In these models, grip strategies were recoded as binary variables (e.g., adult grips as 1 and child grips as 0). Age was included as the fixed effect, while the participant was treated as the random effect in the GLMMs.

The second set of analysis aimed to examine functional development by investigating change in self-feeding events (all feeding events with and without caregiver physical involvement), independent events (the self-feeding events without caregiver physical involvement), and dropping events, with age. Generalized linear models (GLMs) were run in R, with the frequencies of events (i.e., self-feeding events, independent events, and dropping events) as dependent variables and age as an independent variable. Simple linear regressions were conducted in R, with the proportions of events as dependent variables and age as an independent variable.

In the final set of analyses, we examined the correlation between the formal and functional structure. Together, these analyses allowed a comprehensive investigation of the research questions concerning the development of chopstick use and provided valuable insights into the significance of exploring the tool use—chopstick use—in a natural setting.

Results

The purpose of this study was to investigate the developmental trajectory of Chinese children's chopstick use for eating in their home environments. To address this aim, we conducted three primary sets of analyses: The first set of analyses focused on the formal development of chopstick use; the second set of analyses pertained to the functional development of chopstick use; and the third set of analyses examined the relationship between the functional and formal structure of chopstick use. Before conducting the primary analyses, we examined potential correlations between age with eating time and total coded events (self-feeding events, serving events, and dropping events). Eating time was defined as the duration from when the child picked up the chopsticks and started eating to when they finished the meal and put down the chopsticks. The results revealed a significant positive correlation between age and coded events ($r = .335$, $df = 36$, $p = .040$), indicating that children engaged in more total events with increasing age, but no significant correlation between age and eating time ($r = -.045$, $df = 36$, $p = .790$).

Furthermore, we discovered that sixteen participants, whose ages ranged from 31-78 months, changed their grip strategies within a meal (grip modes adopted ranging from 2-7). The frequency of participants' grips is presented in Table 3. To assess the grip variability, we calculated the number of grip modes adopted by each individual and then examined the association between the number of grip modes and age. The results suggested that the number of grip modes adopted by individuals was not significantly correlated with age ($r = .051$, $df = 36$, $p = .760$). Although the findings indicated that grip variability might not change with age, considering individual variability regarding grip strategies can better accommodate individual differences and provide more accurate estimates. Therefore, in the subsequent analyses concerning grip strategies, we conducted additional analyses to account for individual variability in use of different grips.

Table 3. Frequency of Grip Modes. Note: Grip strategy was coded for each event.

Participant	Age in Days	Mode 1	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7	Mode 8
001	658	0	0	0	0	28	0	0
002	795	0	0	0	0	38	0	0
003	875	0	0	0	0	0	15	0
004	917	0	0	0	0	25	0	0
005	944	14	0	15	0	2	1	0
006	1079	0	0	0	0	95	0	0
007	1125	0	0	29	0	0	3	0
008	1164	0	0	22	0	1	0	0
009	1222	0	0	2	0	52	0	0
010	1248	0	0	0	0	11	0	0
011	1317	0	0	0	0	9	0	0
012	1370	42	0	0	0	0	0	0
013	1413	0	0	13	0	0	5	0
014	1429	13	10	7	1	66	1	3
015	1444	13	0	30	0	0	1	0
016	1455	0	0	0	18	0	0	0
017	1551	0	0	29	0	0	0	0
018	1578	0	0	50	0	0	0	0
019	1678	0	0	0	0	54	0	0
020	1739	0	0	20	0	0	0	0
021	1762	0	0	83	0	0	0	0
022	1800	0	0	58	0	0	0	0
023	1810	0	0	0	0	40	0	0
024	1812	14	0	7	0	0	0	0
025	1816	0	0	0	22	0	0	0
026	1904	0	0	39	0	0	0	0
027	1904	0	0	66	0	0	0	0
028	1998	0	0	0	69	0	0	0
029	2016	0	0	44	0	0	21	0
030	2052	0	0	82	1	0	0	0
031	2065	36	0	0	0	0	0	0
032	2075	0	0	78	0	0	0	0
033	2097	1	0	0	0	9	0	0
034	2130	0	0	24	0	0	30	0
035	2205	0	0	43	0	0	38	0
036	2205	45	0	4	0	0	2	0
037	2263	0	0	32	8	0	0	0
038	2376	3	0	1	0	0	55	0

In this set of analyses, we investigated the formal structure of chopstick use by analyzing the grip strategies employed by the participants. Firstly, we focused on the use of adult versus child grip strategies by examining the changes in the frequencies of adult and child grips, as well as the proportion of child grips (calculated by dividing the frequency of child grips by the total frequency of all mode types for each individual) with age. An overview of the grip strategies used by the children is presented in Table 4. The only observed adult grip is Mode 1 (N = 181), while the majority of child grips fell into Mode 4 (N = 778), Mode 5 (N = 119), Mode 6 (N = 430), and Mode 7 (N = 172). We also calculated the mean frequency of coded events by R, which is displayed in Table 5.

In order to determine whether the use of adult or child grip strategies changed with age, we conducted two generalized linear models (GLMs) with a Poisson family. These two models examined the relationship between age and the frequency of adult grips (Mode 1 and 2) as well as age and the frequency of child grips (Mode 3, 4, 5, 6, 7, and 8) respectively. The results from the Poisson GLM on the effect of age on the frequency of *adult* grips revealed a positive effect ($\beta = .0007$, $SE = .0002$, $z = 3.946$, $p < .001$; see Figure 2). These results suggested that with age (ranging from 21 to 78 months), children more frequently adopted adult grips. Despite this slight increase in adult grips with age, child grips remained the predominant modes. However, we detected overdispersion in the Poisson GLM for the frequency of *child* grips, leading us to further test the effect of age on the frequency of child grips using a GLM with a negative binomial family. The negative binomial GLM for child grips provided a better fit to the data compared to the Poisson GLM ($\chi^2(1) = 556.97$, $p < .001$). The negative binomial GLM indicated no age effect on the frequency of child grips ($\beta = .0004$, $SE = .0003$, $z =$

1.325, p = .185). This finding suggested that the frequency of child grips did not change significantly with age within the observed age range (21 to 78 months).

Table 4. Frequency Data: Frequency of Coded Grips.

Grip Mode	Frequency
Adult Grips	181
Mode 1	181
Mode 2	0
Child Grips	1512
Mode 3	10
Mode 4	778
Mode 5	119
Mode 6	430
Mode 7	172
Mode 8	3
Total	1693

Table 5. Frequency Data: Mean Frequency of All Mode Types (with Standard Error).

Grip Mode	Mean Frequency
Adult Grips	4.76 (1.90)
Mode 1	4.76 (1.90)
Mode 2	0
Child Grips	39.79 (4.48)
Mode 3	0.24 (0.24)
Mode 4	20.47 (4.26)
Mode 5	2.90 (1.80)
Mode 6	10.49 (3.42)
Mode 7	4.53 (1.97)
Mode 8	0.07 (0.07)

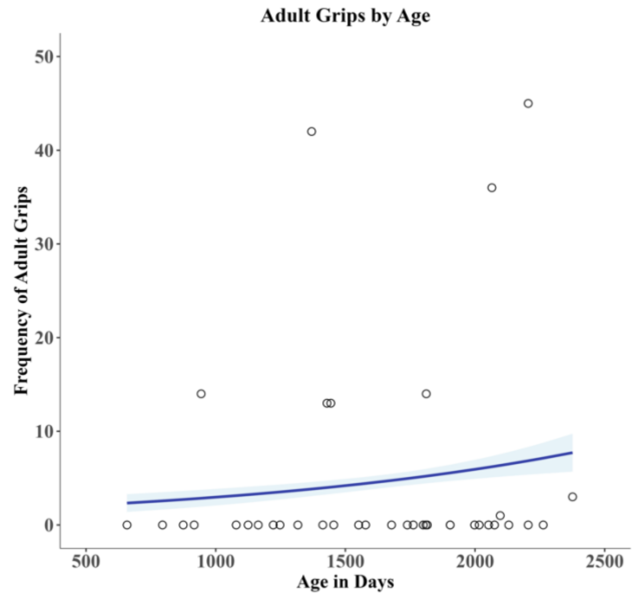

Figure 2. Frequency of adult grips by age in days.

We also calculated the proportion of child grips by dividing the frequency of child grips by the total frequency of all mode types. The mean proportion of child grips is .88 (SEM = .05). To examine changes in the proportion of child grips with age, simple linear regression analysis was conducted. The results did not show any significant association between age and child grips ($p = .469$). In addition, we observed that sixteen children changed their grip strategies within a meal. To account for this grip variability within individuals, we performed a binomial Generalized Linear Mixed Model (GLMM). In this analysis, we recoded adult grips as 1 and child grips as 0. Similarly, the results indicated no significant change in the use of adult versus child grips with age ($\beta = .0001$, SE $= .0030$, $z = .117$, $p = 0.907$). Despite a significant increase in the frequency of adult grips, the results suggested no increase in the proportion of adult grips or a decrease in the proportion of child grips. However, it should be noted that children had a greater number of total events with age ($r = .335$, $df = 36$, $p = .040$), which might lead them to more frequently adopt adult grips as they grew older. Therefore, the proportion analysis is more reliable in this case, indicating that even with increasing age, the proportion of child grips versus adult grips did not change.

Individual grip modes. Secondly, we conducted additional analyses to investigate the change in the use of individual child grips with age. Our focus was specifically on grip modes 4-7, as the frequencies of Mode 3 ($N = 10$ across all tested participants) and Mode 8 ($N = 3$ across all tested participants) were low. Four Poisson GLMs were employed to examine the association between age and the frequency of Mode 4, Mode 5, Mode 6, and Mode 7. The results revealed that age had a significant positive effect on the frequency of Mode 4 ($\beta = .0011$, $SE = .0001$, $z = 12.512$, $p < .001$; see Figure 3), Mode 5 ($\beta = .0017$, $SE = .0003$, $z = 6.515$, $p < .001$; see Figure 4), and Mode 7 ($\beta = .0032$, $SE = .0003$, $z = 11.322$, $p < .001$; see Figure 5). These findings suggested increases in the frequency of Mode 4, Mode 5, and Mode 7 with age. Mode 4 was defined as the thumb, index, and middle fingers controlling both chopsticks; Mode 5 was defined as the thumb and index fingers controlling both chopsticks; Mode 7 was defined as the middle, ring, and thumb fingers holding one chopstick, and the index and thumb holding the other. All three modes are child grip modes but involve a clear division of labor for each finger in using the chopsticks during each food transport event. In contrast, age was found to have a significant negative effect on the frequency of Mode 6 ($\beta = -.0017$, $SE = .0001$, $z = -15.210$, $p < .001$; see Figure 6). Mode 6 was defined as all fingers touching or controlling the chopsticks, and this mode involves variability in the relative positions of the fingers to each chopstick, resulting in less stability. The results indicated a decrease in the frequency of Mode 6 with age.

We conducted additional analyses to examine the correlations between the frequencies of different grip strategies. The results are shown in Table 6. We observed negative associations between the frequency of child grips and the frequency of adult grips ($r = -.416$, $df = 36$, $p = .009$), as well as the frequency of Mode 4 and Mode 6 ($r = -.378$, $df = 36$, $p = .019$). It is important to note that we defined Mode 4 as the thumb, index, and middle fingers controlling the chopsticks, while Mode 6 was defined as all fingers touching or controlling the chopsticks. These results suggested that children who more frequently used child grips were less likely to use adult grips, and children who used Mode 4 grips more frequently were less likely to use Mode 6 grips.

Additionally, we calculated the proportions of Mode 4, Mode5, Mode 6, and Mode 7 out of total grips respectively. Simple regression analyses were conducted to examine the proportions of grip modes 4-7 with age. The proportions of Mode 4, Mode 5, Mode 6, and Mode 7 were calculated by dividing the frequencies of Mode 4, Mode 5, Mode 6, and Mode 7 by the total frequency of all mode types respectively. The results indicated that the proportion of Mode 6 decreased with age ($b = -.0004$, $t(36) = -3.185$, $p = .003$; see Figure 7). However, no significant results were found for Mode 4 ($p = .138$), Mode 5 ($p = .469$) or Mode 7 ($p = .598$).

We conducted additional analyses to examine the correlations between the proportions of different grip strategies. The results are shown in Table 7. We observed negative associations between the proportion of Mode 4 grips and the proportion of Mode 6 grips ($r = -.592$, $df = 36$, $p < .001$). These results suggested that children who were more prone to adopt Mode 4 (one of the child grip modes) grip strategies were less likely to adopt Mode 6 grips (another child grip mode).

Additionally, we conducted binomial GLMMs to examine the use of child grips and the effect of age. For each GLMM test, we recoded each child grip mode (i.e., Mode 4-7) as 1 and the other modes as 0. The GLMMs took into account both the variation in the number of grips observed across individuals and the grip variability nested within each individual. The results revealed a significant increase in the use of Mode 4 ($\beta = .0071$, SE = .0027, $z = 2.627$, $p = .009$), and a significant decrease in the use of Mode 6 ($\beta = -.0400$, SE = .0010, $z = -38.320$, $p < .001$) with increasing age. The GLMMs suggested an increase in the use of Mode 4 and a decrease in the use of Mode 6 compared to the other grip modes.

Summary. The proportion and GLMM results for Mode 4 and Mode 6 aligned with the frequency results. The findings supported that as children became older, they were less likely to rely on Mode 6 grip strategies and instead favored Mode 4 grips. In contrast, the proportion and GLMM binomial results for Mode 5 and Mode 7 were inconsistent with the frequency results. The significant frequency results for Mode 5 and Mode 7 could be attributed to the finding that older children displayed a greater number of total grips ($r = .335$, $df = 36$, $p = .040$). With increasing age, children had more grips and, thus, were more likely to demonstrate Mode 5 and Mode 7 grips. However, the proportion analysis considered the different numbers of grips observed across individuals, while the GLMM binomial considered both the different numbers of grips observed across individuals and the grip variability nested within each individual. It is also important to note that the frequencies for Mode 5 (see Figure 4) and Mode 7 (see Figure 5) were relatively low. Only a few older children showed increases in the frequencies of Mode 5 and Mode 7. In our study, therefore, the proportion and GLMM results are more reliable. As children became older, they were more likely to adopt Mode 4 grip strategies but less likely to adopt Mode 6 grip strategies.

In conclusion, the analyses concerning the formal development of chopstick use collectively indicated that as children became older, they relied more on Mode 4 grips but less on Mode 6 grips. Mode 4 involves a clear division of labor among the fingers when using chopsticks, while Mode 6 involves variability in the relative positions of the fingers to each chopstick, resulting in less stability. These findings thus suggested that with age, children improved the fine motor control of their fingers, leading to more adoption of Mode 4 and less adoption of Mode 6. Nevertheless, we did not observe an increase in the use of adult grips or a decrease in the use of child grips as children became older. These results suggested that children within our tested age range did not predominantly develop the more mature grip strategies (adult versus child grip modes).

Table 6. Frequency Data: Correlations between Frequencies of Grip Strategies.

Measure	Child Grips	Mode 4	Mode 5	Mode 6	Mode 7
Adult Grips	-.416**	-.246	-.108	-.119	-.102
Child Grips		.552***	.110	.362*	.237
Mode 4			-.183	-.378*	.002
Mode 5				-.128	-.102
Mode 6					-.188

Table 7. Proportion Data: Correlations between Proportions of Grip Strategies.

Measure	Mode 4	Mode 5	Mode 6	Mode 7
Child Grips	.255	.134	.232	.135
Mode 4		-.261	-.592***	-.126
Mode 5			-.200	-.128
Mode 6				-.260

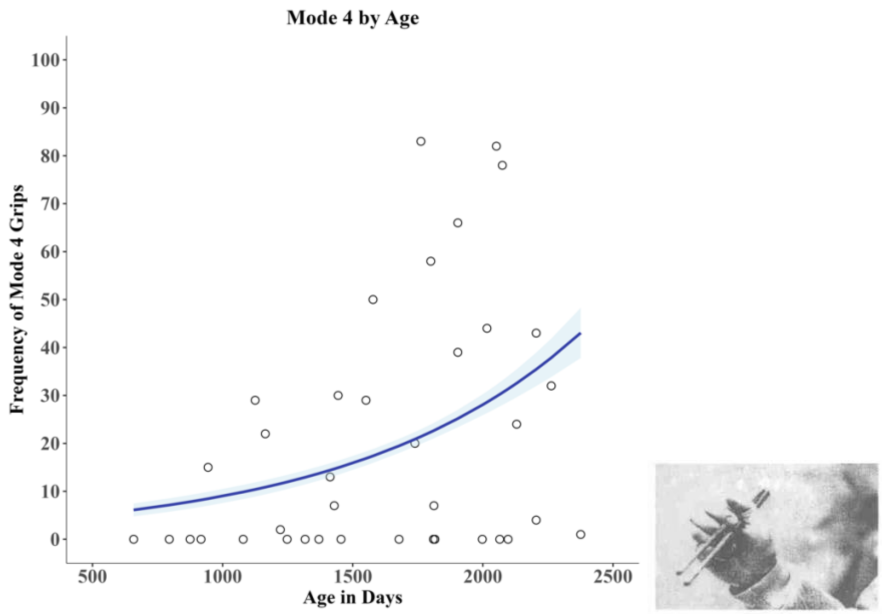

Figure 3. Frequency of Mode 4 grips by age in days.

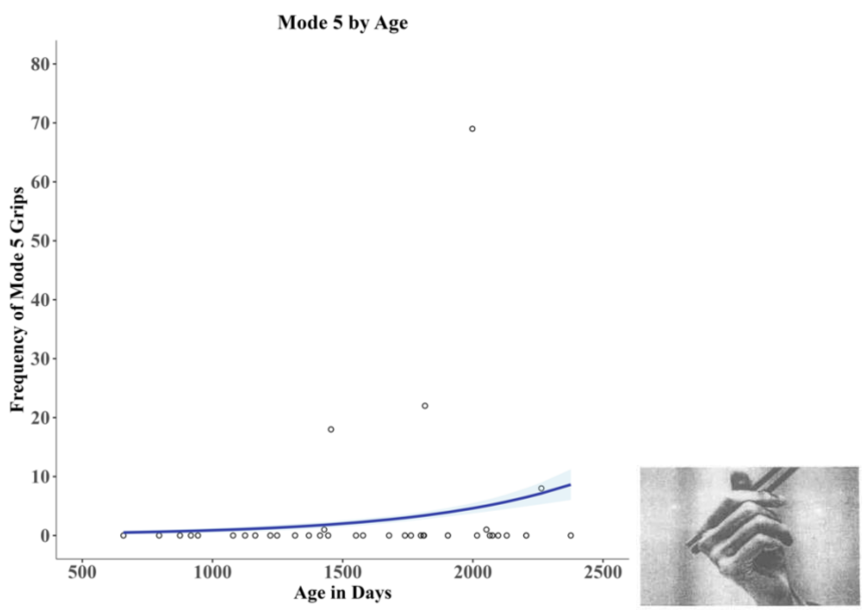

Figure 4. Frequency of Mode 5 grips by age in days.

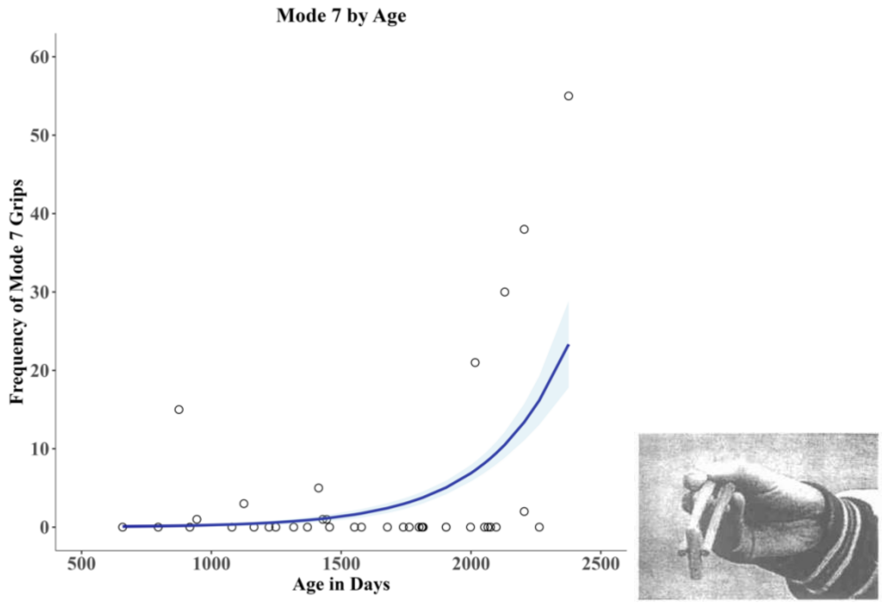

Figure 5. Frequency of Mode 7 grips by age in days.

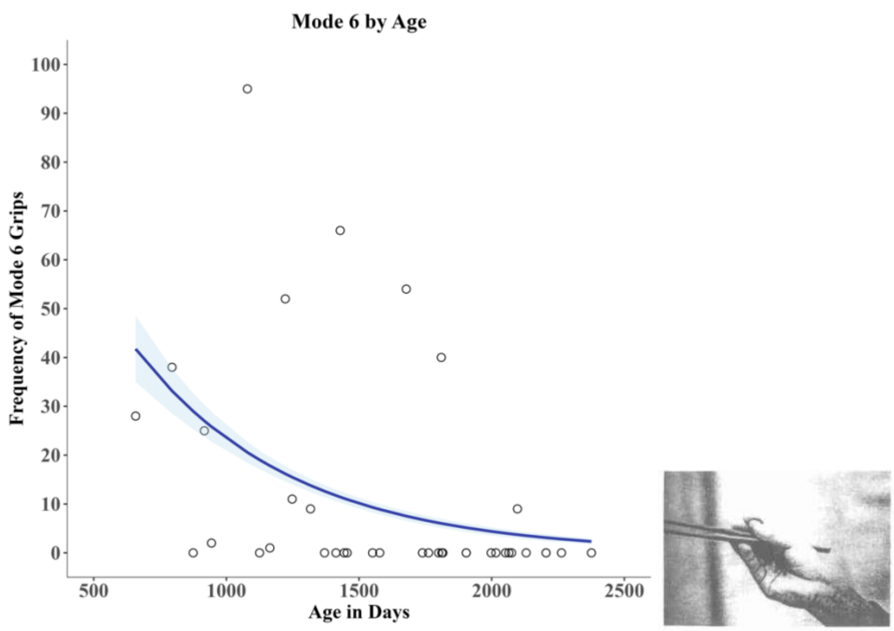

Figure 6. Frequency of Mode 6 grips by age in days.

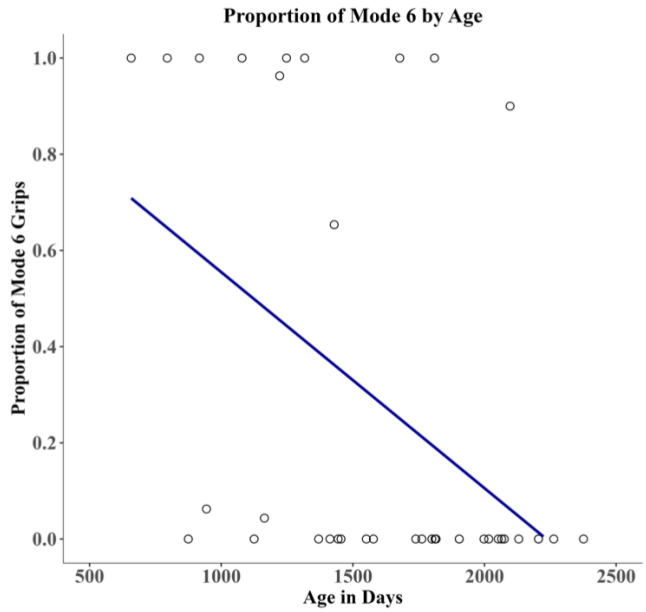

Figure 7. Proportion of Mode 6 grips by age in days. Note that proportion of Mode 6 was calculated by dividing the frequency of Mode 6 grips by the total frequency of all mode types.

Functional structure of chopstick use

The second set of analyses focused on investigating how children develop the functional components of chopstick use in home settings. Table 8 provides an overview of the coded events that were collected, including feeding events, serving events, and dropping events. The mean frequency of events was calculated using R and the results are shown in Table 9. Please note that serving events were excluded from the subsequent analyses. However, these events were still considered as part of the total events, and grip strategies for the serving events were retained in our dataset. In our preliminary analyses regarding the engagement in serving events, we did not observe a significant change with age ($p = .679$). The results could be explained by the possibility that some children simply picked up the food directly from the serving plates with the chopsticks and put it in their mouths. Not every child necessarily served themselves before eating. We observed serving events in 15 children, with 6 children having more than 5 serving events. In Chinese tradition, it is typically expected that individuals serve themselves first by transporting food from the serving plates to their personal bowl and then feed themselves by moving food from their bowl to their mouth. However, children are not always required to adhere to the same practice. Moreover, some children did not share the serving plates with their adult family members and therefore did not have a serving plate at all. Consequently, among the tested children, we did not observe an increase or decrease in the serving events with increasing age.

Initially, three generalized linear models (GLMs) with a Poisson family were fitted to explore the association between age and the frequency of self-feeding, independent feeding, and dropping events separately. However, overdispersion was detected in the models, which led us to test the effect of age on the frequency of these events using GLMs with a negative binomial family. The negative binomial GLMs provided a better fit to the data than the Poisson GLMs, as suggested by the significant chi-square values for self-feeding events ($\chi^2(1) = 255.36$, $p < .001$), independent feeding events ($\chi^2(1) = 302.80$, $p < .001$), and dropping events ($\chi^2(1) = 11.88$, $p < .001$).The results of the negative binomial GLMs showed that age had a significant positive effect on the frequency of self-feeding ($\beta = .0007$, $SE = .0002$, $z = 3.446$, $p < .001$; see Figure 8) and independent feeding events ($\beta = .0008$, $SE = .0002$, $z = 3.563$, $p < .001$; see Figure 9). Conversely, age negatively influenced the frequency of dropping events ($\beta = -.0019$, $SE = .0003$, $z = -5.416$, $p < .001$; see Figure 10). These results indicated that as children grew older, the frequency of self-feeding and independent feeding events increased, while the frequency of dropping events decreased.

Moreover, we found a positive correlation between the frequency of self-feeding events and the frequency of independent feeding events ($r = .993$, $df = 36$, $p < .001$; see Table 10), indicating that participants who engaged in more self-feeding events were also more likely to have more independent feeding events. No significant association was observed between the frequency of self-feeding events ($p = .675$) or independent events ($p = .637$) with the frequency of dropping events.

Table 8. Frequency Data: Frequency of Coded Events.

Event	Frequency
Feeding Events	1505
Independent Feeding Events	1473
Non-Independent Feeding Events	32
Serving Events	99
Dropping Events	89
Total	1693

Table 9. Frequency Data: Mean Frequency of All Event Types (with Standard Error).

Event	Mean Frequency
Feeding Events	39.61 (3.75)
Independent Feeding Events	38.76 (3.91)
Non-Independent Feeding Events	0.84 (0.45)
Serving Events	2.61 (0.93)
Dropping Events	2.34 (0.52)
Total	44.58 (4.08)

Table 10. Frequency Data: Correlations between Frequencies of Events.

Measure	Independent feeding	Dropping
Self-feeding	.993***	-.070
Independent feeding		-.079

Note: Degrees of freedom are shown in parentheses.

*p < .05. **p < .01. ***p < .001.

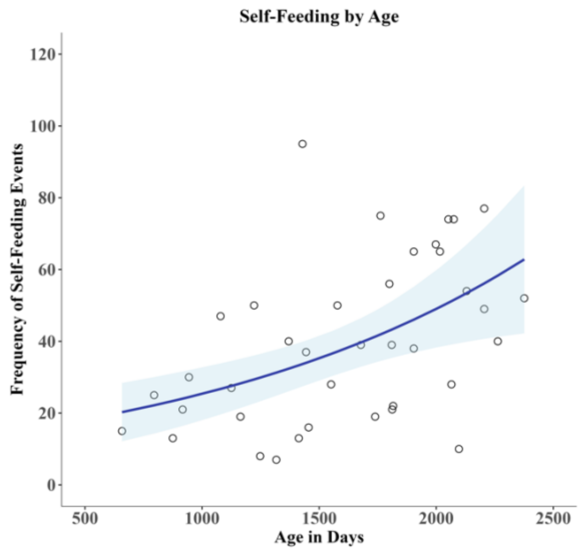

Figure 8. Frequency of self-feeding events by age in days.

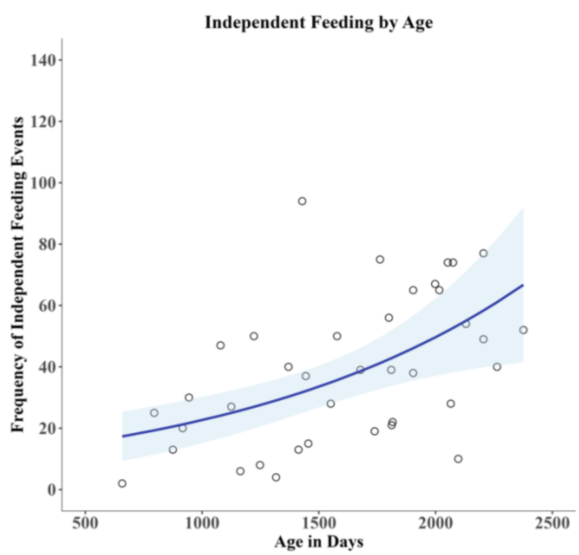

Figure 9. Frequency of independent feeding events by age in days.

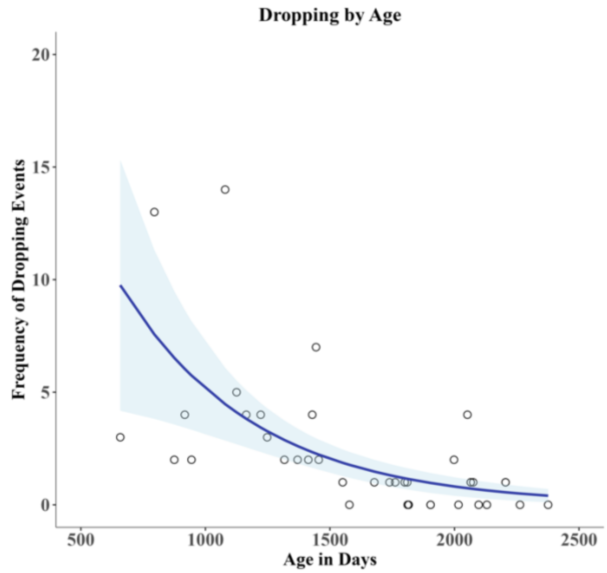

Figure 10. Frequency of dropping events by age in days.

We also calculated the proportion of self-feeding events (calculated by dividing the frequency of self-feeding events by the frequency of total events), independent events (calculated by dividing the frequency of independent events by the frequency of self-feeding events) and dropping events (calculated by dividing the frequency of dropping events by frequency of total events). Table 11 presents the mean proportion of the events. Simple linear regression analyses were conducted in R to examine changes in the proportion of events with age. The analyses revealed that with increasing age, the proportion of self-feeding events ($b = .0002$, $t(36) = 4.62$, $p < .001$; Figure 11) and the proportion of independent feeding events ($b = .0002$, $t(36) = 2.70$, $p = .011$; Figure 12) increased, while the proportion of dropping events decreased ($b = -.0001$, $t(36) = -6.57$, $p < .001$; Figure 13). Overall, these findings suggested that as children grow older, they become more proficient at using chopsticks for self-feeding and independent feeding while reducing dropping.

In addition, we observed a positive association between the proportion of self-feeding events and the proportion of independent feeding events ($r = .439$, $df = 36$, $p = .006$; see Table 12), but a negative association between the proportion of self-feeding events and the proportion of dropping events ($r = -.667$, $df = 36$, $p <.001$; see Table 12). The results suggested that children who engaged more in self-feeding events were more likely to self-feed without caregiver physical involvement (i.e., independent feeding events) and less likely to drop the food (i.e., dropping events). The findings were consistent with our results regarding the frequencies, where we did not observe a significant association between the frequencies of self-feeding and dropping events. Children have different numbers of total events. It is possible that some children who more frequently engaged in self-feeding events might also experience a higher number of dropping events, while other children who more frequently engaged in self-feeding events might engage in a lower number of dropping events. Therefore, in this case, the correlations between the proportions are more meaningful. Children who were more likely to successfully self-feed were more likely to self-feed without caregiver's physical assistance and were less likely to drop food.

Both the frequency and proportion analyses concerning the functional development of chopstick use collectively indicated that as children became older, they were more likely to successfully self-feed and self-feed without caregiver's physical assistance but were less likely to drop food. Additionally, the findings suggested that children who were more likely to successfully self-feed were more likely to self-feed without caregiver's physical assistance and were less likely to drop food.

Table 11. Proportion Data: Mean Proportion of Self-Feeding, Independent Feeding, and Dropping Events (with Standard Error). Note that proportion of self-feeding and dropping events was calculated by dividing their respective frequencies by frequency of total events, and proportion of independent feeding events was calculated by dividing frequency of independent feeding events by frequency of self-feeding events.

Event	Mean Proportion
Self-feeding Events	.88 (.02)
Independent Feeding Events	.94 (.03)
Dropping Events	.07 (.01)

Table 12. Proportion Data: Correlations between Proportions of Events.

Measure	Independent feeding	Dropping
Self-feeding	.439**	-.667***
Independent feeding		-.303

Note: Degrees of freedom are shown in parentheses.

*p < .05. **p < .01. ***p < .001.

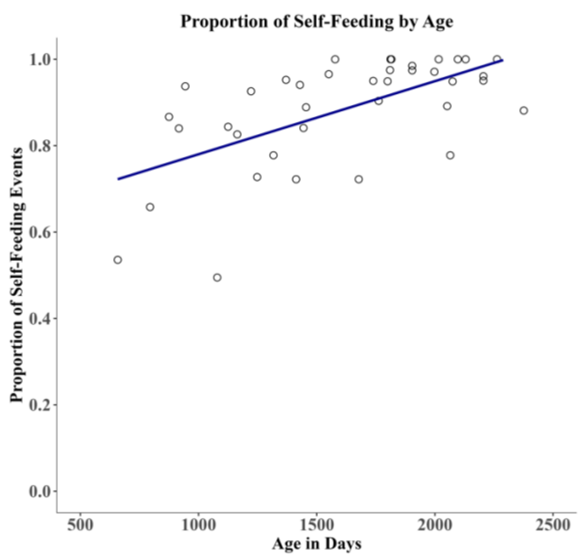

Figure 11. Proportion of self-feeding events by age in days. Note that proportion of self-feeding events was calculated by dividing the frequency of self-feeding events by the frequency of total events.

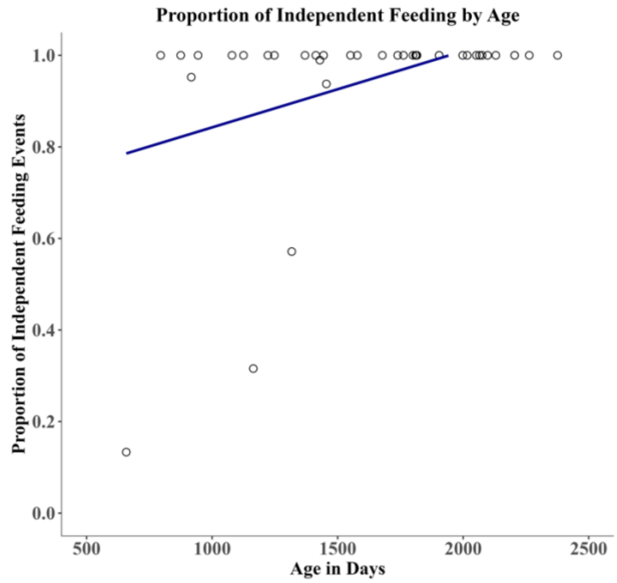

Figure 12. Proportion of independent feeding events by age in days. Note that proportion of independent feeding events was calculated by dividing the frequency of independent feeding events by the frequency of total events.

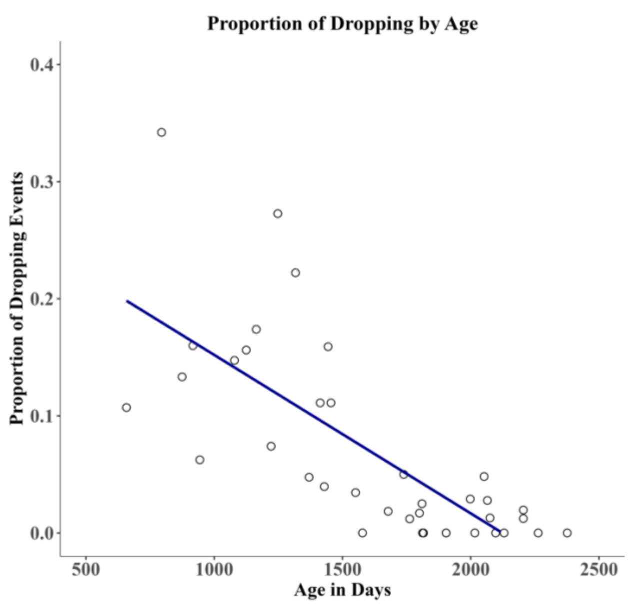

Figure 13. Proportion of dropping events by age in days. Note that proportion of dropping events was calculated by dividing the frequency of dropping events by the frequency of total events.

Correlation between formal and functional structure

The third set of analyses focused on examining the correlation between the formal and functional structure of chopstick use. We first tested the correlations between the frequencies of different events and mode grips. The results of the tests are presented in Table 13. Additionally, we considered the potential influence of eating time on event or grip frequencies, as children who eat for a longer duration may engage in more events. We partialed out eating time while examining the correlations between the frequencies. The results of the partial correlation tests are presented in Table 14. Eating time was the duration from when the child picked up the chopsticks and started eating to when they finished the meal and put down the chopsticks. Preliminary analyses indicated that eating time was not significantly associated with the frequencies of these variables ($r = .012\text{-}.101$, $df = 36$, *p*s $>.50$; see Table 9). We also tested the correlations between the proportions of mode grips and different events. The results are shown in Table 15.

Regarding the simple correlations between the frequencies, we observed positive correlations between the frequency of grip strategies and the frequency of self-feeding events as well as independent events (see Table 13). Specifically, we found that the frequency of child grips correlated positively with the frequencies of self-feeding events ($r = .845$, $df = 36$, $p < .001$) and independent feedings ($r = .830$, $df = 36$, $p < .001$). The significant correlations between child grips with self-feeding ($r = .845$, $df = 36$, $p < .001$) and independent feeding events ($r = .829$, $df = 36$, $p < .001$) remained even when eating time was partialed out (see Table 10). We also observed that the frequency of Mode 4 grips showed positive correlations with the frequencies of self-feeding events ($r = .585$, $df = 36$, $p < .001$) and independent feedings ($r = .577$, $df = 36$, $p < .001$). Similar positive correlations with the frequencies of self-feeding events ($r = .588$, $df = 36$, $p < .001$) and independent feedings ($r = .579$, $df = 36$, $p < .001$) were observed when eating time was partialed out. The findings suggested that children who more frequently adopted child grips or Mode 4 grips were also more likely to engage in self-feeding and independent feeding events. We did not observe a significant association between the frequency of Mode 4 and dropping events either in the simple correlation or partial correlation analyses. In contrast, we observed that the frequency of Mode 6 grips was positively correlated with dropping events ($r = .618$, $df = 36$, $p < .001$), suggesting that participants who used Mode 6 grips more frequently were more likely to drop food during eating. When eating time was partialed out, the frequency of Mode 6 grips was still significantly positively correlated with dropping events ($r = .622$, $df = 36$, $p < .001$).

For the proportion results, significant associations were found between the proportions of grip modes and the proportion measures of the functional structure. Specifically, the proportion of Mode 4 grips exhibited a positive association between the proportion of self-feeding events ($r = .342$, $df = 36$, $p = .035$). Additionally, the proportion of Mode 6 grips exhibited a negative association with the proportions of self-feeding events ($r = -.555$, $df = 36$, $p < .001$) and a positive association with the proportion of dropping events ($r = .486$, $df = 36$, $p = .002$). These results suggested that children who were more prone to adopt Mode 4 grips were more likely to engage in self-feeding events. However, children who were more prone to adopt Mode 6 grips were less likely to engage in self-feeding events but more likely to engage in dropping events. It appeared that while adopting Mode 6, children were less likely to successfully feed themselves and more likely to experience food dropping due to the inherent challenges in finger coordination and chopstick control.

Summary. The analyses regarding the correlation between functional and formal development of chopstick use provided internal validity of the two structures in the development of chopstick use: Children who were more prone to adopt Mode 6 grips were less likely to successfully self-feed (self-feeding events) and more likely to drop their food (dropping events), and children who were more prone to adopt Mode 4 grips were more likely to successfully self-feed.

Table 13. Frequency Data: Correlations between Eating Time and Frequencies of Events and Grips.

Measure	Adult Grips	Child Grips	Mode 4	Mode 5	Mode 6	Mode 7	Self-feeding	Independent feeding	Dropping
Eating Time	.029	.058	-.012	.101	-.020	.071	.071	.050	.077
Adult Grips		-.416**	-.246	-.108	-.119	-.102	.033	.045	-.065
Child Grips			.552***	.110	.362*	.237	.845***	.830***	.193
Mode 4				-.183	-.378*	.002	.585***	.577***	-.213
Mode 5					-.128	-.102	.116	.119	-.070
Mode 6						-.188	.115	.103	.618***
Mode 7							.254	.257	-.212
Self-feeding								.993***	-.070
Independent feeding									-.079

Note: Degrees of freedom are shown in parentheses.

*p < .05. **p < .01. ***p < .001.

Table 14. Frequency Data: Partial Correlations between Frequencies of Events and Grips Controlling for Eating Time.

Measure	Child Grips	Mode 4	Mode 5	Mode 6	Mode 7	Self-feeding	Independent feeding	Dropping
Adult Grips	-.418**	-.245	-.112	-.119	-.105	.031	.044	-.068
Child Grips		.554***	.105	.364*	.234	.845***	.829***	.189
Mode 4			-.183	-.378*	.003	.588***	.579***	-.213
Mode 5				-.127	-.110	.110	.115	-.078
Mode 6					-.187	.117	.105	.622***
Mode 7						.250	.254	-.218
Self-feeding							.993***	-.076
Independent feeding								-.083

Note: Degrees of freedom are shown in parentheses.

*p < .05. **p < .01. ***p < .001.

Table 15. Proportion Data: Correlations between Proportions of Events and Grips.

Measure	Mode 4	Mode 5	Mode 6	Mode 7	Self-feeding	Independent feeding	Dropping
Child Grips	.255	.134	.232	.135	-.102	-.128	.162
Mode 4		-.261	-.592***	-.126	.342**	.070	-.272
Mode 5			-.200	-.128	.180	.061	-.096
Mode 6				-.260	-.555***	-.260	.486**
Mode 7					.060	.122	-.089
Self-feeding						.439**	-.667***
Independent feeding							-.303

Note: Degrees of freedom are shown in parentheses.

*p < .05. **p < .01. ***p < .001.

Discussion

Eating with utensils, such as chopsticks, is an early form of tool use that requires coordination between spatial and motor skills. This skill is also influenced by social and cultural contexts, particularly in the case of Asian children who need to learn to eat with chopsticks. In contrast to the use of Western utensils, which primarily involves hand and arm movements (Connolly & Dalgleish, 1989), chopstick use requires intricate coordination between the hands and fingers, including the precise movements of the fingers in relation to each other and the palm. Previous research on the development of chopstick use has focused primarily on completing specific tasks, such as transporting objects, and investigating the grip strategies in lab settings. These studies have examined changes in grip modes with age and have found that adults and older children at 7 years are more likely to use more mature adult grips but less likely to use less mature ones—child grips—than younger children at 3 years (formal development of chopstick use). However, little is known about how chopstick use develops in real-life eating situations, where children may drop food and adapt their grip strategies to different types of food (functional development of chopstick use). Therefore, this study aimed to examine the natural developmental trajectories of chopstick use in Chinese children in their home environments, addressing gaps in the existing research.

To fill these gaps, we focused on both the formal and functional development of chopstick use, as well as the correlation between these two structures. In terms of the functional structure of chopstick use, our findings were consistent with expectations. As children grew older, they engaged more in self-feeding and independent feeding events, while decreasing their involvement in dropping events, indicating increased competence and independence in using chopsticks. Moreover, the three components of the functional structure were inter-correlated, with children who were more likely to successfully self-feed (self-feeding events) being more likely to feed without caregiver's physical assistance (independent feeding events) and less likely to drop food (dropping events).

Regarding the formal structure of chopstick use, we did not observe a significant increase in the use of adult grips or a decrease in the use of child grips within the children's age range from 21 to 78 months. However, we found that children were more likely to use Mode 4 grips (where the thumb, index, and middle fingers control the chopsticks) and less likely to use Mode 6 grips (where all fingers touch or control the chopsticks) as they grew older. Additionally, there were associations between different child grip modes, with children who used Mode 4 grips being less likely to use Mode 6 grips. These findings highlight the interplay between different components of the formal structure.

Furthermore, we found associations between the formal and functional structures. Specifically, we observed that children who more often adopted Mode 4 grips were more likely to successfully self-feed (self-feeding events), while those who more often adopted Mode 6 were less likely to successfully self-feed (self-feeding events) and more likely to drop food (dropping events). Together, the findings provided the first evidence of construct validity for the formal and functional structures in natural child chopstick use.

One possible explanation for the findings regarding the formal structure is that children in the tested age range (21-78months) primarily focused on developing their ability to assign specific roles to each finger in manipulating chopsticks and refining their finger coordination. This could account for the decrease in the use of Mode 6 grip and the increase in the adoption of Mode 4 grips. Mode 6 refers to the grip where all fingers touch or control the chopsticks. Children typically exhibited greater variability in the relative positions of their fingers to each chopstick when using this mode compared to other grip modes, resulting in less stability in finger control and an increased likelihood of dropping food. As children grew older, they became less likely to adopt this grip mode, potentially because they developed more refined strategies that provided greater stability and control.

On the other hand, Mode 4 refers to the grip where the thumb, index, and middle fingers control the chopsticks. In this mode, the division of labor among the fingers is clear and stable. Although it is not the most mature grip strategy, children may be more likely to successfully transport food to their mouths using this mode. Therefore, with increasing age, children were more likely to adopt this grip mode as it allowed for relatively more efficient chopstick manipulation.

Regarding the proportions of adult versus child grips, our results did not show significant change with age. One possible explanation for this finding is that children may develop adult grip strategies for chopstick use at a later stage. Lin and colleagues (2001) found that older children aged 7 years and adults were more likely to adopt adult grips and less likely to adopt child grips compared to younger children aged 3 years. Specifically, they reported the following proportions of children adopting adult grips: 3.7% for children aged 3 years, 16.6% for children aged 4 years, 5.9% for children aged 5 years, 20.5% for children aged 6 years, and 26.9% for children aged 7 years. The results did not suggest a linear progression in grip development across different age groups of children. Instead, it appears that there was a considerable increase in the adoption of adult grips among children somewhere between 5-7 years. However, in our study, the age of the children ranged from 21 to 78 months (1 to 6 years). Given the limited age range of participants, further research with a larger and more diverse age range of children is necessary to gain a more comprehensive understanding of the developmental trajectory of grip strategies in chopstick use.

Development of eating with chopsticks

Children learn through practice, and natural eating with chopsticks develops over mealtimes. Our study revealed that children engaged in an average of 41 transports during mealtime. Extrapolating this to a day, children would accumulate approximately 120 food transports, and over a year, this would amount to 43,800 occasions. Through this extensive practice, children gradually built up their skill of eating with chopsticks. As they became older, they developed competence in using chopsticks, dropping less food and successfully self-feeding more, as well as gaining independence in self-feeding without caregiver’s physical assistance. This process of development shows similarities with locomotor development, where infants developed natural walking skills through massive amounts of variable, time-distributed practice (Adolph et al., 2012). Infants practiced approximately 2400 steps per hour, totaling 14,000 steps over the course of a waking day. With more walking experience, infants took more steps, traveled farther distances, and fell less.

In addition, Han and Adolph (2020) suggested that children could also learn from errors during spontaneous exploration while locomoting. Children occasionally experienced falls while engaging in various activities when walking. However, in the early stages of walking development, infants might adapt their bodies and behaviors to mitigate the consequences of falls. For example, they might take reactive steps to maintain their balance, flex their knees during landing to reduce impacts by falling, and grasp available supports to reduce fall speed. As a result, the relatively low costs and high rewards associated with walking and play allow infants to quickly resume exploration within seconds after a fall. In our investigation of chopstick use for eating, we observed a similar learning process. Natural eating with chopsticks is not always smooth. Children start and stop at will, transport food, sometimes modify their grip strategies, and occasionally drop and pick up food again. Younger children might thus adopt strategies (e.g., Mode 6) to mitigate the error costs by grasping chopsticks with all fingers controlling both chopsticks to ensure they do not drop the chopsticks. If children do happen to drop the chopsticks, children may become frustrated, and caregivers are more likely to show concern. However, with the mitigated error costs by applying all fingers to grasp the chopsticks and the high rewards from eating, younger children continued exploring and learning the use of chopsticks even after dropping food. This learning process helps them gradually improve their chopstick use skills through immense practice and become more proficient in using chopsticks for eating.

Natural eating with chopsticks develops through practice and drops: Initially, young children may struggle with coordinating their hand and finger movements, resulting in more dropping events. They may also face challenges in grasping and manipulating the chopsticks, lacking a proper division of labor among their fingers, leading to more food drops and a greater reliance on less mature grip modes (e.g., Mode 6). However, with increased experience and practice, children become more skilled at manipulating the chopsticks and are able to feed themselves without assistance.

Meanwhile, they rely more on grip strategies that offer greater stability and precision in finger and chopstick movements. This development is reflected in the adoption of relatively more mature grip modes (e.g., Mode 4), which enables better coordination among their fingers and more precise manipulation of the chopsticks, leading to more successful self-feedings.

Limitations

Despite these findings, it is important to acknowledge the limitations of this study. One limitation is that we investigated the development of chopstick use with individual's age, but we did not consider the actual time children have been using chopsticks for eating. Different individuals may have started using chopsticks at different ages. Although research on locomotor development suggests a concurrent change in age and walking time (Adolph et al., 2012), more empirical evidence is needed regarding the specific impact of eating experience with chopsticks on skill development. To further support our suggestion that children learn through practice rather than solely relying on physiological aging, future investigation is necessary.

Social support from caregivers also plays a significant role in children's development of utensil use. During mealtime, caregivers may provide physical assistance by touching the child's hands or chopsticks. While we considered such occasions in our analysis, caregivers may also demonstrate how to use the chopsticks without physical contact or provide verbal guidance. These aspects were not addressed in this study. Future research should systematically examine the influence of caregivers on the development of chopstick use, including the demonstrations and verbal guidance they provide. Understanding how different types of caregiver support impact children's chopstick use skills can provide valuable insights into the learning processes involved in using chopsticks for eating.

Conclusions

How do young Chinese children develop the skill of eating with chopsticks? Our findings suggest potential developmental trajectories in both the functional and formal structures of chopstick use. These trajectories indicate a developmental progression towards better control and stability in handling chopsticks, as well as improved competence and independence in their use for eating. The findings also highlight the importance of practice and drops in acquiring proficiency and independence in using chopsticks. This study additionally provides the first evidence of construct validity for the formal and functional structures in natural child chopstick use. Moreover, our study suggests the need for future research to examine the associations between eating time with chopsticks and the development of chopstick use in natural eating contexts and investigate the influence of social factors, such as caregiver involvement, on the development of chopstick use.

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Biography

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