Article

Not peer-reviewed version

Do Computerized False Belief Tasks Impact Mentalizing Ability in People with Williams Syndrome?

Ching-fen Hsu * and Shi-yu Rao

Posted Date: 14 March 2023

doi: 10.20944/preprints202303.0252.v1

Keywords: false belief; Williams syndrome; theory of mind; social cognition

Article

Do Computerized False Belief Tasks Impact Mentalizing Ability in People with Williams Syndrome?

Ching-Fen Hsu * and Shi-Yu Rao

School of Foreign Languages, Laboratory for Language Pathology and Developmental Neurosciences, Hunan University, Lushan Road (S), Yuelu District, Changsha 410082, Hunan Province, China
* Correspondence: chinghsu@hnu.edu.cn; Tel.: +86-0731-88821135; Fax: +86-0731-88821135

Abstract: Background: People with Williams syndrome (WS) are characterized with hypersociability, fluency in languages, and advantageous face-processing skills, leading to the proposal of a social module. Previous studies on the mentalizing abilities of people with WS using two-dimensional pictures and mindreading from eyes, including normal-like, delayed, and deviant behaviors, have yielded mixed results. This study thus examined the mentalizing ability of people with WS through structured computerized animations of false belief tasks to investigate whether inferences about other people's minds can be improved in this population. **Method**: Participants were shown animations with unexpected location and content changes. After viewing each animation, participants had to answer four types of questions: character identification, reality, memory, and false belief. Their responses were recorded and analyzed. **Results**: Comprehension of false belief was observed in 4-year-old healthy children, whereas children with WS showed unsuccessful comprehension of false belief (until they attained a mental age of 5.3 years), suggesting an improvement in theory of mind resulting from viewing structured computerized animations. This age is earlier than that reported by previous studies for using theory of mind to pass false belief tests (8.5 years old), even challenging the age at which individuals failed to pass the tests (12.10 years old). **Conclusions**: Structured computerized animations enhanced the mentalizing ability of people with WS to a certain extent. Compared to the typically developing controls, people with WS presented with a lower developmental level in processing false belief tasks. The educational implication of this study is to develop computerized social skills interventions for people with WS.

Keywords: false belief; Williams syndrome; theory of mind; social cognition

---

1. Introduction

Mentalizing other people's minds is an important cognitive ability related to social cognition and interpersonal communication. It is realized through multiple aspects such as language, face processing, and joint attention. Premack and Woodruff (1978) first proposed theory of mind to account for the mentalizing ability in chimpanzees and subsequently in humans by Wimmer and Perner (1983). Theory of mind or mindreading refers to the ability to understand others' mental states and to predict their behaviors. This mindreading ability has been investigated among people with neurodevelopmental disabilities, including those with Williams syndrome (WS).

A previous study reported that people with WS (9–23 years old) showed better mindreading ability in the first-order tests of theory of mind compared to those with autism; however, the study lacked a control group (Karmiloff-Smith, Kilma, Bellugi, Grant, & Baron-Cohen, 1995). In another study with 13 participants with WS (17–37 years old) who completed a mindreading test from the eyes, people with WS performed better in inferring mental states compared to those with Prader-Willi syndrome (PWS; another population with genetic deficits on chromosome 15 at q11-13 region with even cognitive profiles of language and visuospatial abilities); however, they were worse than the typically developing controls (Tager-Flusberg, Boshart, & Baron-Cohen, 1998). These results suggest that people with WS are relatively good at mentalizing other people's minds from their eyes but have not reached the developmental level of the typically developing controls. There is still a gap in the mindreading ability of people with WS, when compared to typical developers.

Another study conducted false belief tasks of location and content change with people with WS (3–8 years old), people with PWS, and people with non-specific mental retardation (NSMR), confirming worse impairment in mentalizing others' minds in people with WS (Tager-Flusberg & Sullivan, 2000). Children with WS responded least accurately to the false belief questions compared to those with PWS and NSMR. This finding suggests that a deficiency of theory of mind in people with WS starts early in childhood. This view is comparable with the representational redescription model proposed by Karmiloff-Smith (1992). The ability to mentalize other people's minds in people with WS results from a modularized process together with fluent language and social interaction given the innate tendency to, for example, look at human faces. However, early gene mutation has a devastating influence on later development in people with WS, as proposed in neuroconstructivism (Karmiloff-Smith, 1998).

In addition to the hallmark false belief tests, explanation of actions has been used to evaluate the ability of theory of mind in people with WS (Tager-Flusberg & Sullivan, 2000). In Tager-Flusberg and Sullivan's study, four types of stories probing desire, emotion, cognition, and causal reasoning were tested on three groups of participants (people with WS, PWS, and NSMR). The results showed that people with WS (4–8 years old) were no better than the other two groups in explaining human actions. Additionally, people with WS performed worse for stories of causal reasoning compared to those of cognition (the condition the other two groups struggled the most with). This finding suggests that people with WS were impaired in processing non-psychological or physical-related causal reasoning; however, their mentalizing ability was at the same level as that of people with PWS and NSMR. It should be noted, however, that the test stimuli were verbal narrations without visual pictures, which have been demonstrated to improve the ability of integrating information in people with WS because of the social information of the pictures (Hsu, 2013c).

Social skills interventions have proven effective for people with neurodevelopmental disorders. Extant research has reported the possibility of using such interventions for people with autism by demonstrating a lack of significant difference between traditional, face-to-face social skills training programs and behavioral cognitive intervention programs (Soares, Bausback, Beard, Higinbotham, Bunge, & Gengoux, 2021). Fisher and Morin (2017) developed interventions for people with WS by using the training programs of *UCLA PEERs for Adolescent Programs* manual (Laugeson & Frankel, 2010), *Health and Family Life Education Common Curriculum* (UNICEF, 2019), and *Think Social* (Winner, 2008). Before implementing these programs, parental questionnaires were distributed to understand the social skills of people with WS. Next, discussions were held with parents of adults with WS to confirm their social skill problems and to develop specific intervention programs for them (social skills training program for people with WS [SSTP-WS]). Pre- and post-tests of social skills interventions on people with WS were conducted, with effective results observed within 2 days. This study demonstrates that SSTP-WS is a promising intervention tool for people with WS.

Fisher, Kammes, Black, and Cwiakala (2022) conducted an 8-week long SSTP with people with WS, further confirming the acceptability, feasibility, and efficacy of this training program. Both studies demonstrated effective face-to-face telehealth social skills training in people with WS. The current study examined the effect of advanced technological research method to improve the mentalizing ability of people with WS. It was hypothesized that computer-based technology would impact the cognitive behaviors of people with WS to a certain extent.

2. Method

2.1. Participants

Twenty-two people with WS (mean CA = 9.9, SD = 3.1, 12F/10M, range = 5.9–18.1; mean MA = 6.4, SD = 2.4, range = 3.8–12.3) were recruited for the location-change false belief task; 17 people with WS (mean CA = 10.3, SD = 3.3, 8F/9M, range = 6.6–18.1; mean MA = 6.7, SD = 2.4, range = 4.0–12.3) were recruited for the content-change false belief task. All people with WS were diagnosed with missing genes on chromosome 7q11.23 in hospitals at various ages. Healthy controls were individually matched with people with WS based on their CA and MA using the Wechsler Scale of Intelligence for Children. The gender of each participant with WS and healthy control was also matched. No difference was observed in age between the CA or MA group and people with WS.

Twenty healthy 3- and 4-year-old children from four kindergartens in Changsha, China, were recruited in each group. The age difference between the groups was significant [3 years old: mean age = 3.4, SD = 0.2; 4 years old: mean age = 4.2, SD = 0.2; $F_{(1, 40)} = 164.14$, $p < 0.001$]. Our aim was to verify the validity of the testing trials and to examine whether the transition from 3 to 4 years of age is critical in the Chinese education environment for children's development pertaining to false beliefs. Standard false belief tasks with changes in location and content were conducted. The background information of all participants is listed in Table 1. This study was approved by the Institutional Review Board of the School of Foreign Languages of Hunan University, China. Before the experiment began, each participant's guardian signed an informed consent form.

Table 1. Background Information of Participants.

Task	Group	N	F: M	Mean CA (SD)	Range	Mean MA (SD)	Range
Unexpected Location Task	CA	22	12:10	9.9 (3.3)	5.7-18.7		
	MA	22	12:10	6.3 (2.3)	3.8-12.2		
	WS	22	12:10	9.9 (3.1)	5.9-18.1	6.4 (2.4)	3.8-12.3
	3yr	20	10:10	3.4 (0.2)	3.0-3.6		
	4yr	20	10:10	4.2 (0.2)	4.0-4.6		
Unexpected Content Task	CA	17	8:9	10.4 (3.5)	6.3-18.7		
	MA	17	8:9	6.6 (2.4)	4.0-12.2		
	WS	17	8:9	10.3 (3.3)	6.6-18.1	6.7 (2.4)	4.0-12.3
	3yr	20	10:10	3.4 (0.2)	3.0-3.6		
	4yr	20	10:10	4.2 (0.2)	4.0-4.6		

Note: F: M refers to the ratio of female: male; CA stands for chronological age; MA stands for mental age; WS stands for Williams syndrome; SD stands for standard deviation.

2.2. Materials and design

Two false belief tasks were used: the unexpected location-change task and the unexpected content-change task. Twenty trials were conducted for each task. All trials were presented in the form of cartoon videos (length of the location task = 26.20 min, mean = 1.32, SD = 0.05; length of the content task = 26.83 min, mean = 1.35, SD = 0.07; total length of the two tasks = 53.03 min). Two additional trials were performed for practice before the experiment began (length of the location task = 2.70 min, mean = 1.35, SD = 0.07; length of the content task = 2.82 min, mean = 1.42, SD = 0.02; total length of the two tasks = 5.52 min). Each trial comprised a scenario with two cartoon protagonists acting out a script.

Five pairs of cartoon characters were presented in the two tasks: Winnie the Pooh and Tigger, Mickey Mouse and Donald Duck, Pleasant Goat and Grey Wolf, Tom (cat) and Jerry (mouse), and SpongeBob and Patrick Star. These cartoon characters were selected from the most popular films in the last 3 to 5 years in China. The names of all chosen characters were of the same length when written in Chinese. Every child was familiar with each protagonist. No pair of cartoon characters was displayed consecutively.

In the beginning of each location-change video, two characters were introduced consecutively. Each scenario followed a template with the sequence of a general setting, an action, a motivation, a confirmed motivation action, a character who leaves temporarily, key actions, a false belief-inducing

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 March 2023 doi:10.20944/preprints202303.0252.v1

action, and comprehension questions. An example of the unexpected location-change task is provided in Table 2. Each scenario was well-designed in its structure and details. In the parts relating to motivation and key actions, three movements were included. The crucial turning point was the key actions that might introduce false beliefs to participants. Each scenario was followed by comprehension questions. Each participant responded to all questions regarding their recognition of cartoon characters, memory, reality, and the false belief scenarios. To keep participants focused on the scenarios of the videos, narrations were presented in male and female voices alternatively for every five trials.

Table 2. An Example of the Unexpected Location-Change Task (with Original Chinese Text).

Structure	Contexts
General Setting	唐老鸭和米老鼠一起坐在阳台上晒太阳。 Donald Duck and Mickey Mouse sat on the balcony and enjoyed a sunbath.
Action	唐老鸭把花放进篮子里。 Donald Duck put the flowers in the basket.
Motivation (three actions)	唐老鸭和米老鼠坐了一会，唐老鸭觉得有点渴，想去喝水。 Donald Duck and Mickey Mouse sat for a while (verb 1). Donald Duck was thirsty (verb 2) and went to drink water (verb 3).
Confirmed Motivation Action	唐老鸭离开阳台，喝水去了。 Donald Duck left the balcony and went to drink water.
Left Character	这时，阳台上只剩下米老鼠。 At this time, only Mickey Mouse was left on the balcony.
Key Actions (one setting + three actions)	米老鼠很调皮，把花从篮子里拿出来，放进柜子里，再关上柜门。 Mickey Mouse was very naughty. He took the flowers out of the basket, put them in the cabinet, and then closed the door.
False Belief-Inducing Setting	过了一会，唐老鸭回到阳台，想闻闻花香。 After a while, Donald Duck returned to the balcony and wanted to smell the flowers.
Attention Arousing Greeting	好，小朋友， OK, dear,
Recognition Question 1	你知道哪个是唐老鸭？ Do you know which character is Donald Duck?
Recognition Question 2	你知道哪个是米老鼠？ Do you know which character is Mickey Mouse?
Belief Question	唐老鸭喝完水，回到阳台，唐老鸭会去哪里找花？ Donald Duck finished drinking water and went back to the balcony. Where would Donald Duck look for flowers?

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 March 2023 doi:10.20944/preprints202303.0252.v1

Reality Question	现在花在哪里？ Where are the flowers now?
Memory Question	一开始唐老鸭把花放在哪里？ Where did Donald Duck put the flowers at first?

Several factors were considered while creating scenarios based on children's developmental stages in language comprehension. Time expressions, for example, *before*, *after*, and *then*, were removed and replaced with non-referential time point terms, such as *okay* and *at that time*. Children were able to understand the sequence of actions upon watching the videos. Parallel video structures of the content-change task were created, as shown in Table 3. All participants received two practice trials before the experiment began. The computerized scenarios designed in this study have not been used before in any related tests.

Table 3. An Example of the Unexpected Content-Change Task (with Original Chinese Text).

Structure	Contexts
General Setting	喜羊羊和灰太狼一起来到图书馆。 A pleasant goat and grey wolf came to the library together.
Action	他们在图书馆里准备看书。 They are ready to read the books in the library.
Motivation (three actions)	翻开书，喜羊羊和灰太狼有点看不清，想找副眼镜。 Opening the books, the pleasant goat and grey wolf could not see clearly.
Confirmed Motivation Action	于是，喜羊羊离开图书馆，去找眼镜。 So, the pleasant goat left the library to look for eyeglasses.
Left Character	这时，图书馆里只剩下灰太狼。 At this time, only the grey wolf was left in the library.
Key Actions (one setting; three actions)	喜羊羊回到图书馆，把眼镜盒放到灰太狼面前。这时候灰太狼要去拿书包，灰太狼离开了图书馆。 Pleasant goat returned to the library and put the eyeglasses box in front of the grey wolf. Meanwhile, the grey wolf was going to get his school bag. Grey wolf left the library.
False Belief-Inducing Setting	哇，喜羊羊真调皮，居然把饼干装在眼镜盒里。 Wow, the pleasant goat was so naughty that he put cookies in his eyeglasses box.
Attention Arousing Greeting	好，小朋友， OK, dear,
Recognition Question 1	你知道哪个是喜羊羊？ Do you know which character is the pleasant goat?
Recognition Question 2	你知道哪个是灰太狼？ Do you know which character is the grey wolf?
Belief Question	灰太狼还没有打开过眼镜盒，灰太狼觉得眼镜盒里装的是什么？

 doi:10.20944/preprints202303.0252.v1

	Grey wolf has not opened the eyeglasses box yet. What does the grey wolf think is in the eyeglasses box?
Reality Question	现在你知道眼镜盒里装的是什么？ What is in the eyeglasses box now?
Memory Question	一开始喜羊羊去拿的眼镜盒里装的是什么？ What was in the eyeglasses box when pleasant goat went to get it at first?

2.3. Procedure

Participants were tested in a quiet room individually. Each participant watched videos with unexpected location-change scenarios or content-change scenarios counterbalanced. At the end of each scenario, each participant responded to the comprehension questions probing false belief and four control questions (recognition of two characters, memory, reality). The experimenter recorded participants' responses on answer sheets simultaneously. Trials were presented randomly.

3. Results

3.1. Analyses of healthy 3- and 4-year old controls

Correct responses, including accurate recognition of characters (character-recognition questions), accurate inferences about false beliefs (false belief questions), accurate identification of the location or content of the targeted object in the final situation (reality question), and accurate indication of the original position of or content in the container (memory question), were analyzed.

Non-parametric binomial statistical tests were used to analyze the location-change and content-change task data. Both 3- and 4-year-old children passed the recognition of characters test ($p < 0.001$); both groups showed highly accurate percentage values (the location-change task, 100% in both age groups [in 3-year-olds, SD = 0.05; 4-year-olds, SD = 0]; the content-change task, 99% [SD = 0.07] in 3-year-olds and 100% [SD = 0] in 4-year-olds) in comprehension of characters in the videos. The memory question also reached high accuracy levels in both groups at $p < 0.001$ (the location-change task, 89% [SD = 0.31] in 3-year-olds, 100% [SD = 0] in 4-year-olds; the content-change task, 89% [SD = 0.31] in 3-year-olds, 99% [SD = 0.07] in 4-year-olds). Fisher's exact tests showed significant difference in the memory test between the 3- and 4-year-old groups in the location-change task ($p = 0.00007$) and in the content-change task ($p = 0.005$). Both age groups responded to the reality question correctly at $p < 0.001$ (the location-change task, 3-year-olds, 90% [SD = 0.31], 4-year-olds, 100% [SD = 0]; the content-change task, 3-year-olds, 95% [SD = 0.23], 4-year-olds, 100% [SD = 0]). Fisher's exact test showed significant difference between the 3- and 4-year-old groups regarding the reality question in the location-change task ($p = 0.0015$); however, the difference was not significant between groups in the content-change task.

Regarding the false belief questions, 3-year-old children showed extremely low accuracy in the location-change task (5%, SD = 0.22) and in the content-change task (4%, SD = 0.20) at $p < 0.001$. Whereas, 4-year-old children showed a relatively high accuracy in responding to the false belief question of location (99%, SD = 0.10) and of content (98%, SD = 0.14) at $p < 0.001$. Multivariate analyses of variance revealed group differences in false belief tasks, $F_{(1, 798)} = 6142.09$, $p < 0.001$, $\eta^2 = 0.885$, suggesting that 4-year-olds had attained the milestone of discerning false belief compared to 3-year-olds. Fisher's exact test also showed a significant difference between the 3- and 4-year-old groups at $p < 0.00001$ regarding the false belief question in the location-change and content-change tasks. Group differences were observed along the reality [$F_{(1,798)} = 46.81$, $p < 0.001$, $\eta^2 = 0.055$] and memory [$F_{(1,798)} = 48.06$, $p < 0.001$, $\eta^2 = 0.057$] dimensions, indicating higher accuracy among 4-year-olds than 3-year-olds. Put together, these differences imply generally advanced cognitive development among older children.

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 14 March 2023 doi:10.20944/preprints202303.0252.v1

3.2. *Analyses of the unexpected location-change task*

Multivariate analyses of variance were performed with the correct responses to each trial of each type in the unexpected location-change task as the within-participant factor and groups as the between-participant factor. No differences emerged in the two questions regarding recognition of the two characters across groups (100% in all groups), suggesting clear comprehension of the tested animated videos by children. Significant differences were observed in responding to questions related to memory, reality, and false belief [memory, $F_{(2, 1317)} = 32.01$, $p < 0.001$, $\eta^2 = 0.46$; reality, $F_{(2, 1317)} = 20.90$, $p < 0.001$, $\eta^2 = 0.031$; false belief, $F_{(2, 1317)} = 175.86$, $p < 0.001$, $\eta^2 = 0.211$]. The question of reality reached significance, as detected by the Tukey method [CA (100%, SD = 0) vs. MA (96%, SD = 0.187), $p < 0.001$; CA vs. WS (92%, SD = 0.278), $p < 0.001$; MA vs. WS, $p < 0.001$]. Another significance was observed for the question on memory [CA (100%, SD = 0) vs. MA (99%, SD = 0.082), $p > 0.05$; CA vs. WS (92%, SD = 0.271), $p < 0.001$; MA vs. WS, $p < 0.001$]. Still another difference was uncovered for the key question on false belief [CA (100%, SD = 0) vs. MA (91%, SD = 0.291), $p < 0.001$; CA vs. WS (60%, SD = 0.490), $p < 0.001$; MA vs. WS, $p < 0.001$]. Overall, people with WS showed the lowest accuracy, and the MA controls demonstrated accuracy values within the in-between range. This finding suggests that people with WS fared worse in mentalizing other people's minds.

A nonparametric binomial statistical test was used to analyze each group based on each type of question. The results revealed significant differences in comprehending questions on character recognition, reality, and memory [two character recognition questions: CA, 100%; MA, 100%; WS, 100%; memory question: CA, 100%; MA, 99%; WS, 92%; reality question: CA, 100%; MA, 96%; WS, 92%]. Significant difference also emerged in response to false beliefs between people with WS and the MA and CA controls at $p < 0.001$ [CA, 100%; MA, 91%; WS, 60%]. People with WS were accurate only 60% of the time regarding the question related to the location-change false belief task.

3.3. *Analyses of the unexpected content-change task*

Multivariate variance analyses with question types as the within-participants factor and groups as the between-participants factor were conducted. The results revealed no group differences in character recognition questions (all participants recognized cartoon characters correctly) but significant group difference in those pertaining to memory [$F_{(2,1017)} = 5.35$, $p = 0.005$, $\eta^2 = 0.010$], reality [$F_{(2,1017)} = 3.02$, $p = 0.049$, $\eta^2 = 0.006$], and false belief [$F_{(2,1017)} = 197.09$, $p < 0.001$, $\eta^2 = 0.279$]. Post-hoc analyses with the Least Significant Difference method revealed differences between the WS group (99%, SD = 0.094) and the CA (100%, SD = 0) and MA groups (97%, SD = 0.161) in their responses to reality questions ($p = 0.034$). No difference emerged between the CA and MA groups. Another significant difference in comparison using the Tukey method was observed from the distinct processing of the WS group (63%, SD = 0.483) and the control groups (CA, 100%, SD = 0; MA, 100%, SD = 0) in their response to false belief ($p < 0.001$). No difference was observed between the CA and MA groups. Concerning questions about memory, the Tukey method revealed that the difference between the CA and MA groups had reached significance ($p = 0.004$). No difference was observed between the WS group and the healthy controls.

Separate analyses of each group revealed significant differences in response to each type of question at $p < 0.001$. The pattern of response to false belief was reversed in the WS group. People with WS passed the false belief test 63% of the time (in contrast to the 100% passing rate of the CA and MA groups), suggesting that people with WS were impaired in the processing of false beliefs.

4. Discussion

The present study examined the understanding of first-order false beliefs in people with WS. Structured animated video clips were used to test unexpected content and locations, revealing that people with WS made inferences through the differentiation of false belief from reality and memory by viewing the animations. In this study, the mean age of participants with WS (60% in the location-change task, 63% in the content-change task) who passed the false belief tests was 5.3 years old. This age was still over the critical age of 4 years old in passing the false belief tasks. Our results not only demonstrate the different processing passing rates of location-change and content-change false belief tasks but also show that structured computerized animations enhance the mentalizing ability of people with WS. The number of people with WS who passed the false belief tasks was higher than that of those who failed to do so; however, people with WS showed the lowest accuracy among all groups. This finding confirms our hypothesis that technological tools can improve performance of false belief in people with WS (Hsu, 2021).

The age difference (i.e., 5.3 vs. 4) implies discrepancy in processing between computerized three-dimension animation and traditional two-dimensional images. The cause of the difference might be due to deficiency in integrating contextual information in people with WS (Hsu, Karmiloff-Smith, Tzeng, Chin, & Wang, 2007; Hsu & Karmiloff-Smith, 2008; Hsu, 2013a, 2013b, 2013c, 2014a, 2014b, 2016b, 2017b, 2020a, 2020b, 2023; Hsu & Chen, 2014c; Hsu & Tzeng, 2011), difficulty in understanding task demands (Van Herwegen, Dimitriou, & Runblad, 2013), or superficial knowledge of lexical semantics (Hsu & Lv, 2023). This deficiency was evident in integrating word meaning into context during sentence processing (Hsu, 2013a, 2023), connecting words in a semantic organization (Hsu, 2017b, 2020a), delayed performances on causal inference through comprehension of ambiguous words (Hsu, 2013a), deviant contextual integration using pictures (Hsu, 2013c), and deviant integration of propositions in people with WS (Hsu & Tzeng, 2011). Further atypical neurological information processing across verbal and nonverbal domains was reported in conceptual formation (Hsu, Karmiloff-Smith, Tzeng, Chin, & Wang, 2007), semantic priming (Hsu, 2017b), and face recognition (Hsu & Chen, 2014c; Mills, Alvarez, St George, Appelbaum, Bellugi, & Neville, 2000). These deficits might have caused an impaired ability to mentalize other people's minds in people with WS. Although computerized video animations did improve the mentalizing ability of people with WS, the deviant pattern in false belief revealed in the current study implies atypical development of theory of mind in this population. Hence, a relatively developed social module for people with WS is proposed.

This atypical development leads to deficient social cognition in people with WS. Social cognition of people with WS is not at a level equivalent to that of chronological age-matched healthy controls (Einfeld, Tonge, & Florio, 1997). Einfeld, Tonge, and Florio et al. (1997) reported behavioral and emotional disturbance in people with WS aged 9.2 years old compared to populations with intellectual disabilities aged 12 years old. People with WS were significantly over-affectionate, sensitive to anxiety, preoccupied with certain ideas, inappropriately happy or elated, wandering around, and repeating words repeatedly. These emotional problems may result in atypical social behaviors of people with WS and a deficient ability to mentalize other people's minds. Einfeld et al.'s finding (1997) was in line with that of Hsu and Lv (2022) in which people with WS were atypical in emotion recognition through narrations and replacement while aiming at targeted emotions. Moreover, people with WS were delayed in their processing of *anger* and *surprise* emotions compared to the typically developing controls.

Language ability is an important factor that can influence the development of theory of mind. Evidence from people with deafness and those with visual impairments showed delayed development of mentalizing abilities in both compared to typically developing controls due to the paucity of language input during the early stages of their lives (Garfield, Peterson, & Perry, 2001). Hence, people with WS were deficient in their ability to mentalize other people's minds due to impaired language abilities tested through their understanding of false beliefs. However, in a prior study, language was shown to not play a role in comprehension of other people's minds in people with WS as their language ability did not predict their mindreading ability in verbal and low-verbal false belief tasks (Van Herwegen, Dimitriou, & Runblad, 2013).

Different patterns of social interactions with their parents, siblings, and other people early in the lives of people with WS might be a determining factor influencing their development of mentalizing other people's minds and social interactions. Moreover, the atypical processing of faces may contribute to the deviant social cognition of people with WS (Pavlova, Heiz, Sokolov, & Barisnikov, 2016). Even the ability to understand narrations expressed in nouns or verbs caused different contextual effects on people with WS (Hsu, 2023). However, executive functions evaluated by working memory and tapping task were unrelated to false belief performances in people with WS (Tager-Flusberg, Sullivan, & Boshart, 2014). Although emotional cues helped people with WS understand others' minds better (Campos et al., 2017), future studies exploring false beliefs at the neurological level in people with WS are needed to lend support to the relatively developed social module. The current study contributes to using advanced computerized animations to improve the mindreading ability of people with WS and exploring the possibility of educational interventions for this population in the future.

Acknowledgements: The corresponding author would like to thank the Fundamental Research Funds of the Central Universities in China for the startup funding received from Hunan University (531118010366), partial support from the Nature Science Funds of Hunan Province (2021JJ30100) and National Social Science Fund of China (22FYYB033). Gratitude is extended to the WS participants and their parents for their support in this study. Special thanks go to Children's Hospital Zhejiang University School of Medicine, The First kindergarten Attached to National University of Defense Technology, Changsha Xinjiabo kindergarten Attached to Golden Future Preschool Education Group, and Wang Cheng Jinhai School in Changsha for their kind support.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Campos, R., Castilla-Martinez, P., & Sotillo, M. (2017). False belief attribution in children with Williams syndrome: The answer is in the emotion. *Journal of Intellectual Disability Research*, *61*, 1003–1010.
2. Einfeld, S. T., Tonge, B. J., & Florio, T. (1997). Behavioral and emotional disturbance in individuals with Williams syndrome. *American Journal on Mental Retardation*, *102*(1), 45–53.
3. Fisher, M. H., Kammes, R. R., Black, R. S., & Cwiakala, K. (2022). A distance-delivered social skills program for young adults with Williams syndrome: Evaluating feasibility and preliminary efficacy. *Journal of Autism and Developmental Disorders*, *52*, 5162–5176.
4. Fisher, M. H., & Morin, L. (2017). Addressing social skills deficits in adults with Williams syndrome. *Research in Developmental Disabilities*, *71*, 77–87.
5. Garfield, J. L., Peterson, C. C., & Perry, T. (2001). Social cognition, language acquisition and the development of the theory of mind. *Mind and Language*, *6*(5), 494–541.
6. Hsu, C. F. (2016b). Contextual coherence of information integration in people with Williams syndrome: Implications for cognitive interventions. *Proceeding of the 15th International Symposium on Chinese Languages and Linguistics*.
7. Hsu, C. F. (2023). Contextual effects on figurative processing of nouns and verbs in people with Williams syndrome. *Research in Developmental Disabilities*, *134*, 104429.
8. Hsu, C. F. (2013a). Contextual integration of causal coherence in people with Williams syndrome. *Research in Developmental Disabilities*, *34*(10), 3332–3342.
9. Hsu, C. F. (2013b). Cross-modal contextual coherence of semantic integration in people with Williams syndrome. *Research in Developmental Disabilities*, *34*(12), 4319–4327.
10. Hsu, C. F. (2014a). Cross-domain investigation of weak central coherence in people with Williams syndrome: Asymmetrical brain and behavioural performances in verbal and nonverbal domains. In Olivia H. Porter (Ed.), *Semantic Memory: Neurobiology, Disorders and Therapeutic Strategies for Improvement* (pp. 71–82). Nova Science Publishers.
11. Hsu, C. F. (2013c). Is the contextual effect weak in people with Williams syndrome? An investigation of information integration ability using pictures. *Research in Developmental Disabilities*, *34*(3), 932–939.
12. Hsu, C. F. (2014b). Modality effect of contextual integration in people with Williams syndrome. *Research in Developmental Disabilities*, *35*(7), 1571–1578.
13. **Hsu, C. F.** (2020a). Neural correlates of causal inferences and semantic priming in people with Williams syndrome: An fMRI study. *Journal of Intellectual Disabilities-Diagnosis and Treatment*, *8*(4), 698–709.
14. Hsu, C. F. (2017b). Semantic priming and associative priming in people with Williams syndrome. In Lowell T. Duncan (Ed.), *Advances in Health and Disease*, Vol. 2. (pp. 171–196). Nova Science Publisher.
15. **Hsu, C. F.** (2020b). Understanding emotion language through events and words in people with Williams syndrome. *Child Neuropsychology*, *26*(8), 1091–1111.
16. Hsu, C. F. (2021). New pathways of brain plasticity on people with developmental disabilities: A review of cognitive interventions with technologies. *Global Journal of Intellectual and Developmental Disabilities*, *9*(2), 555756.
17. Hsu, C. F., & Chen, J. Y. (2014c). Deviant neural correlates of configural detection in facial processing of people with Williams syndrome. *Bulletin of Special Education*, *39*(1), 61–84.
18. Hsu, C. F., & Karmiloff-Smith, A. (2008). Language and Williams syndrome. *Annual Review of Applied Linguistics*, *28*, 191–204.

19. Hsu, C. F., & Lv, P. (2022). Investigating basic emotions in people with Williams syndrome. *Research in Developmental Disabilities*, *129*, 104308.
20. Hsu, C. F., & Lv, P. (2023). Emotion Priming in People with Williams Syndrome. *Brain Sciences: Insight into the ability of language understanding and writing in neurodevelopmental disorders* (special issue for Developmental Neurosciences section).
21. Hsu, C. F., Karmiloff-Smith, A., Tzeng, O., Chin, R. T., & Wang, H. C. (2007). Semantic knowledge in Williams syndrome: Insights from comparing behavioural and brain processes in false memory tasks. *Proceedings of the 6th IEEE International Conference on Development and Learning*, *6*, 48–52.
22. Hsu, C. F., & Tzeng, O. (2011). Contextual effect in people with Williams syndrome. *Research in Developmental Disabilities*, *32*(2), 781–787.
23. Karmiloff-Smith, A. (1992). *Beyond Modularity: A developmental perspective on cognitive science*. Cambridge: MIT Press.
24. Karmiloff-Smith, A. (1998). Development itself is the key to understanding developmental disorders. *Trends in Cognitive Science*, *2*(10), 389–398.
25. Karmiloff-Smith, A., Klima, E., Bellugi, U., Grant, J., & Baron-Cohen, S. (1995). Is there a social module? Language, face processing, and theory of mind in individuals with Williams syndrome. *Journal of Cognitive Neuroscience*, *7*(2), 196–208.
26. Laugeson, E. A., & Frankel, F. (2010). *Social skills for teenagers with developmental and autism spectrum disorders: The PEERS treatment manual*. New York: Routledge.
27. Mills, D. L., Alvarez, T. D., St George, M., Appelbaum, L. G., Bellugi, U., & Neville, H. (2000). Electrophysiological studies of face processing in Williams syndrome. *Journal of Cognitive Neuroscience*, *12*(Supplement), 47–64.
28. Pavlova, M. A., Heiz, J., Sokolov, A. N., & Barisnikov, K. (2016). Social cognition in Williams syndrome: Face tuning. *Frontiers in Psychology*, 27531986.
29. Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, *1*(4), 515–526.
30. Soares, E., Bausback, K., Beard, C. L., Higinbotham, M., Bunge, E. L., & Gengoux, G. W. (2021). Social skills training for autism spectrum disorders: A meta-analysis of in-person and technological interventions. *Journal of Technology in Behavioral Science*, *6*, 166–180.
31. Tager-Flusberg, H., Boshart, J., & Baron-Cohen, S. (1998). Reading the windows to the soul: Evidence of domain-specific sparing in Williams syndrome. *Journal of Cognitive Neuroscience*, *10*(5), 631–639.
32. Tager-Flusberg, H., & Sullivan, K. (2000). A componential view of theory of mind: Evidence from Williams syndrome. *Cognition*, *76*, 59–89.
33. Tager-Flusberg, H., Sullivan, K., & Boshart, J. (2014). Executive functions and performance on false belief tasks. *Developmental Neuropsychology*, *13*(4), 487–493.
34. UNICEF Health and Family Life Education (HFLE) common curriculum: self and interpersonal relationships theme unit. 2009 Retrieved May 16, 2017 from www.educan.org/sites/educan.org/files/SIP_1.pdfwww.educan.org/sites/educan.org/files/SIP_1.pdf.
35. Van Herwegen, J., Dimitriou, D., & Rundblad, G. (2013). Performance on verbal and non-verbal false belief tasks: Evidence from children with Williams syndrome. *Journal of Communication Disorders*, *46*(5-6), 440–448.
36. Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, *13*(1), 103–128.
37. Winner, M. G. (2008). *Think social! a social thinking curriculum for school-age students*. Santa Clara, CA: Think Social Publishing.