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Decision-Making in Adolescents with Profound Hearing Loss

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Abstract

People with profound hearing loss show differences in language-related cognitive functions that may affect decision-making processes, but few studies have examined their decision-making behavior. The current study used the Iowa Gambling Task and the Game of Dice Task to explore the decision-making characteristics of adolescents with profound hearing loss. In the Iowa Gambling Task, deaf adolescents were more inclined to choose from the deck of infrequent losses with large immediate gains and larger future losses. In the Game of Dice Task, the deaf adolescents showed a preference for high-risk choices with high gains and high losses. These results suggest that deaf adolescents show a stronger preference for choices with immediate high gains and underestimate the potential risks, which may be related to differences in executive function or utilization of feedback.

According to data from the World Health Organization (WHO), there are 360 million deaf and hard-of-hearing people worldwide, of whom 32 million are children, and the global cost of solving hearing loss is 750 billion international dollars per year (World Health Organization [WHO], 2017). Profound hearing loss indicates a hearing threshold of more than 81db, which means that one can only perceive a loud sound as a shock. Moreover, the term *deafness* applies to individuals with severe or profound hearing loss (greater than 61db), which implies very little or no hearing (WHO, 2016). In the present study, deaf adolescents with a hearing threshold of more than 91db participated in our experiments.

The most direct influence caused by deafness is the communication difference and the speed of individual language development (WHO, 2017). Furthermore, language development is associated with behavioral problems in deaf and hard-of-hearing children (Stevenson et al., 2010), and auditory deprivation or language deprivation caused by deafness might affect executive function (Figueras, Edwards, & Langdon, 2008; Oberg & Lukomski, 2011).

Hall, Eigsti, Bortfeld, and Lillo-Martin (2017) reported that deaf children exposed from birth to a natural sign language showed no difference in some aspects of executive function, but a significantly greater risk than hearing participants of elevated scores on the inhibition and working memory subscales of the Behavioral Rating Inventory of Executive Function (BRIEF). The BRIEF, which was developed by Gioia, Isquith, Guy, and Kenworthy (2000a, 2000b), includes eight theoretically and empirically based clinical scales ("Inhibition," "Shift," "Emotional Control," "Initiate," "Working Memory," "Plan/Organize," "Organization of Materials" and "Monitor"). High scores indicate problems with executive functioning. Hintermair (2013) suggested that deaf and hard-of-hearing children from schools for the deaf scored higher than their hearing peers on the BRIEF. In addition, deaf children with cochlear implants were at a three to four times greater risk of clinically significant deficits in executive functioning based on the BRIEF compared with their hearing peers (Kronenberger, Beer, Castellanos, Pisoni, & Miyamoto, 2014). In fact, both users and nonusers of cochlear implants were reported to exhibit significantly greater difficulties in comprehension/conceptual learning, factual memory, sustained sequential processing, working memory, and novel problem solving, which are measured by the Scale of Learning, Executive, and Attention Functioning, consisting of 40

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questions about recent experiences or behaviors characterizing executive function (Marschark et al., 2017).

Results from behavioral tasks are similar to the results from scales; it seems to be more difficult for deaf children to discriminate a target and inhibit responses to nontarget information. Mitchell and Quittner (1996) revealed that deaf children had more difficulty than hearing children in discriminating the signal from the noise in the Vigilance Continuous Performance Test (e.g., recognizing a 1 followed by a 9 in the center of a screen). They also showed difficulty in inhibiting responses to nontarget information in the Distractibility Continuous Performance Test (e.g., inhibiting a response to irrelevant numerical stimuli on the left and right sides). Moreover, deaf children tend to exhibit greater impulsivity in the Knock and Tap task and poorer inhibition in the Day-Night/One-Two task (Figueras et al., 2008).

According to Botvinick and Braver (2015), executive function could be treated as a domain of reward-based decision-making, and decision-making is also treated as one key aspect of executive functioning in many reviews (Crean, Crane, & Mason, 2011; Crews & Boettiger, 2009; Volkow, Wang, Fowler, Tomasi, & Telang, 2011). As executive function is inevitably involved in individuals' decision-making behavior, and is associated with language development, it may be interesting to explore decision-making behavior in deaf students.

The degrees of uncertainty and the amount of useful information available, such as the possible consequences and their probabilities, are important parameters in decision-making; therefore, there are at least two types of decision-making. In the first, there is no explicit knowledge of the possible outcomes or the probabilities of reward or punishment; the decision-maker must discover useful information and determine the quality of the options by processing feedback on previous choices. In the second, information about the potential consequences of various choices and their probabilities is explicit, and the decisions can be made on the basis of this knowledge of the situation and associated consequences, which can be used to evaluate the rewards and punishments (Brand, Labudda, & Markowitsch, 2006; Brand, Recknor, Grabenhorst, & Bechara, 2007). In the literature, the first type is often termed decision-making under ambiguity, which is often measured with the Iowa Gambling Task (Bechara, Damasio, & Damasio, 2000; Bechara, Damasio, Damasio, & Anderson, 1994), while the second is decision-making under risk, measured with the Game of Dice Task (Brand, Fujiwara, et al., 2005; Brand, Kalbe, et al., 2005). Simultaneous use of the Iowa Gambling Task and the Game of Dice Task can allow exploration of the characteristics of decision-making under two different conditions of ambiguity and risk (Buelow & Wirth, 2017; Zhang, Wang, Zhu, Yu, & Chen, 2015).

In addition, both the tasks require learning of rules, but the Iowa Gambling Task relies on implicit learning, whereas the Game of Dice Task relies on explicit learning. In the Iowa Gambling Task, participants learn to understand the rules through the reward or punishment resulting from their selections, even including feedback from somatic markers and related emotional states, according to the somatic marker hypothesis (Bechara et al., 2000; Bechara, Damasio, Damasio, & Lee, 1999; Bechara, Damasio, Tranel, & Damasio, 2005; Werner, Duschek, & Schandry, 2009). Similarly, they also learn to understand the rules through feedback on their selections in the Game of Dice Task, although their performance on the task depends partly on explicit learning (Brand, 2008). Euteneuer et al. (2009) suggests that patients with Parkinson's disease show performance deficits on the Game of Dice Task and reduced sensitivity to negative feedback; Svaldi, Philipsen, and Matthies (2012) reveal that women with borderline personality disorder make risky decisions significantly more often than a control group and show a reduced capacity to advantageously utilize feedback. If participants cannot experience the normal feedback of reward and punishment, they may perform differently in the Game of Dice Task.

Differences in language development lead to variability in cognitive function, especially executive function, and executive function plays an important role in decision-making tasks; therefore, the performance of deaf adolescents on decision-making tasks is worth further exploration. However, to our knowledge, there is no direct comparison of decision-making performance under ambiguity and under risk in deaf participants. The Iowa Gambling Task and the Game of Dice Task were used in the present study to explore the decision-making behavior of deaf adolescents under ambiguity and risk.

Materials and Methods

Participants

Both the Iowa Gambling Task and the Game of Dice Task were completed by 36 deaf adolescents (deaf group) and 36 hearing adolescents (hearing group). The hearing participants were the same for the two tasks (age: 16.72 ± 1.14 years; years of education: 9.36 ± 1.25; 17 boys); seven deaf participants differed between the two tasks. The mean age and years of education of the 36 deaf participants (23 boys) in the Iowa Gambling Task were 17.14 ± 2.05 years old and 8.53 ± 1.73 years, and the mean age and years of education of the 36 deaf participants (21 boys) in the Game of Dice Task were 16.99 ± 1.95 years old and 8.25 ± 1.83 years. The deaf group was recruited from two schools for deaf adolescents in two medium-sized cities, whose entrance examination showed that all participants had hearing loss of 91 dB or more, communicated with sign language, and all were born deaf or deaf before 2 years old. The hearing group consisted of high school students from another school in one of the two cities where the deaf adolescents were recruited, who had never learned sign language. All participants were right-handed, had no history of mental illness, and took no psychotropic drugs during the experiment; their parents signed informed consent forms before the experiment, and the local Ethics Committee approved the study. The age difference between the participant groups was not significant ($t = 1.07$, $p > .05$), while the average duration of education of the deaf group was significantly lower than that of the control group (Iowa Gambling Task: $t = -2.34$, $p < .05$; Game of Dice Task: $t = -3.02$, $p < .01$).

Intelligence Tests

The intelligence of all participants was assessed using Raven's Progressive Matrices and the Hiskey-Nebraska Test of Learning Aptitude. The latter is a non-verbal intelligence test designed by Hiskey (1966) for deaf people aged 3–17 years, and it is also applicable for adults (revised by Qu, Sun, and Zhang (1996)). The intelligence of all participants was normal (scores were above 80).

Decision-making Tasks

Iowa Gambling Task

In the Iowa Gambling Task (see Figure 1), participants began with 2,000 Yuan and were asked to click the mouse to choose cards from one of four decks (A, B, C, or D); after each choice, they won or lost a certain amount of money. Each selection from Deck A or B resulted in a gain of 100 Yuan, whereas a choice from Deck C or D provided a gain of 50 Yuan. However, over the course of ten selections from Deck A or B, there was also a total loss of 1,250 Yuan (net gain: −250 = 10 × 100 − 1,250), whereas smaller penalties meant that over 10 selections from Deck C or D, the loss was only 250 Yuan (net gain: 250 = 10 × 50 − 250). Thus, choosing cards from Deck A or B meant high immediate gains but even higher losses, making these desks the disadvantageous choice, while choosing cards from Deck C or D meant small immediate gains, but even smaller losses; these decks were therefore the advantageous choice. In short, choosing from Deck A or B resulted in a negative future outcome, while choosing from Deck C or D resulted in a positive future outcome. Moreover, both Decks A and C carried a 50% chance of losing money while also winning the standard amount money for that deck, while Decks B and D carried only a 10% chance of a penalty in addition to the normal win. That is, Decks A and C involved frequent losses, while Decks B and D involved infrequent losses (Bechara et al., 1994, 2005). The whole task was divided into five blocks, each consisting of 20 trials, enabling analysis of changes in the decision-making process throughout the task. The experiment was programmed using E-Prime™ software (Psychology Software Tools, Pittsburgh, PA).

Game of Dice Task

The Game of Dice Task (see Figure 2) is a decision paradigm proposed by Brand, Fujiwara, et al. (2005) whose rules are given explicitly to the participants, in contrast to the Iowa Gambling Task. At the beginning of the experiment, each participant had 1,000 Yuan, and they were told to win as much as they could within 18 rolls of the die. Before each throw, the participants first had to choose a single number or a combination of two, three, or four numbers in an attempt to predict the result of the throw. Their choice would correspond to a fixed probability of winning or losing a specified amount: choosing one number offered the chance of a 1,000 Yuan win (with a probability of 1/6), a combination of two numbers offered the chance of a 500 Yuan win (with a probability of 2/6), choosing a combination of three numbers offered the chance of a 200 Yuan win (with a probability of 3/6), and a combination of four numbers offered the chance of a 100 Yuan win (with a probability of 4/6). The outcomes of the die were pseudorandom, and in order to balance the order, every number on the die appeared three times across the entire task. Choosing a single number or a combination of two numbers was regarded as a risky decision for their lower probabilities of winning, while choosing three or four numbers was regarded as a non-risky decision for their higher probabilities of winning (Brand & Altstötter-Gleich, 2008; Brand, Grabenhorst, Starcke, Vandekerckhove, & Markowitsch, 2007; Brand, Recknor, et al., 2007). The experimental program used in the current study was developed by Brand, Fujiwara, et al. (2005).

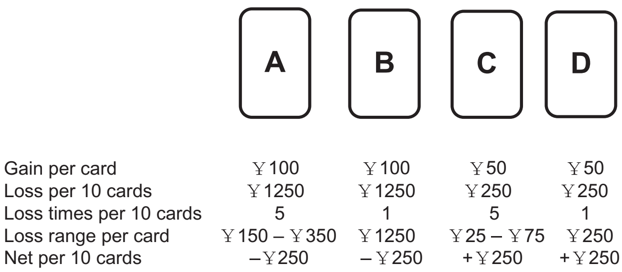

Figure 1 The Iowa Gambling Task paradigm. Each deck (A, B, C, and D) offers a fixed gain with each card, and a probability of either a range of losses or a fixed loss. The overall expected values of drawing 10 cards from each deck are shown in the bottom row. Adapted from Bechara et al. (2005).

Procedure

All participants first filled in their demographic information and took the Raven's Progressive Matrices and the Hiskey-Nebraska Test of Learning Aptitude in a quiet, well-lit, ventilated room. Participants with normal intelligence were invited to complete the two gambling tasks on a portable computer (HP Compap6520s, screen resolution 1,280 × 800). Each participant was asked to complete the Iowa Gambling Task first, and then Game of Dice Task after a 10-min rest; seven deaf students only completed the Iowa Gambling Task; therefore, seven additional deaf students were recruited to participate only in the Game of Dice Task after completing the IQ test. Here the Iowa Gambling Task was administered before the Game of Dice Task, because we wanted to avoid the possibility of subjects applying their explicit knowledge about the contingencies of the GDT to the IGT (Labudda et al., 2009). The participants who completed the Iowa Gambling Task were required to rank the four decks from good to bad (six deaf participants and three hearing participants did not provide the evaluation). There was no practice for either task, but the participants were given detailed instructions to inform them how to complete the task before the experiment.

Results

Intelligence Tests

The deaf group scored significantly lower than the hearing group on the Raven's Progressive Matrices and the Hiskey-

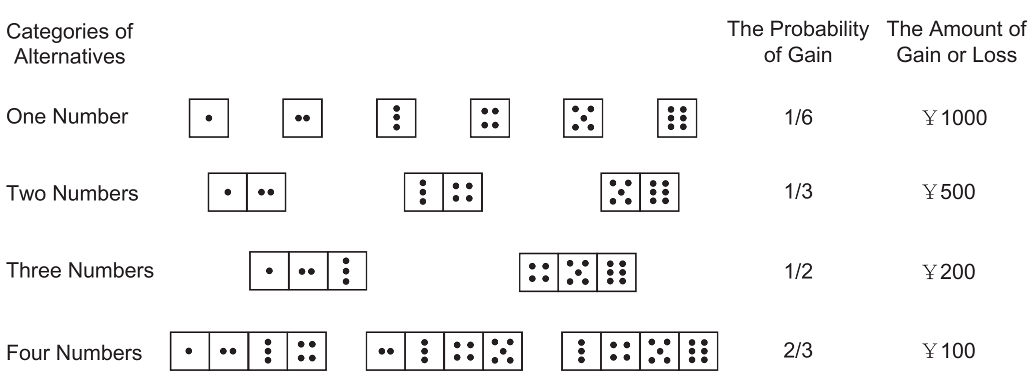

Figure 2 The Game of Dice Task paradigm. An illustration of the probability of winning, and amounts offered for a win, when different numbers are chosen in the Game of Dice Task. Adapted from Brand, Grabenhorst, et al. (2007).

Table 1 Comparison of intelligence between deaf group and control group in the Iowa Gambling Task

	Deaf group (M ± SD)	Control group (M ± SD)	t	df	p
RIQ	98.03 ± 8.43	107.83 ± 11.92	−4.030	62.98	.000
H-NIQ	94.75 ± 6.72	109.44 ± 9.82	−7.410	70.00	.000

RIQ = Raven IQ, H-NIQ = IQ measured by Hiskey-Nebraska Test of Learning Aptitude.

Table 2 Comparison of intelligence between deaf group and control group in the Game of Dice Task

	Deaf group (M ± SD)	Control group (M ± SD)	t	df	p
RIQ	97.31 ± 8.77	107.83 ± 11.92	−4.268	64.28	.000
H-NIQ	91.44 ± 10.66	109.44 ± 9.82	−7.452	70.00	.000

RIQ = Raven IQ, H-NIQ = IQ measured by Hiskey-Nebraska Test of Learning Aptitude.

Nebraska Test of Learning Aptitude, indicating that the intellectual level of the deaf group was not as same as that of the hearing group (see Tables 1 and 2). Thus, Raven IQ (RIQ) and IQ measured by Hiskey-Nebraska Test of Learning Aptitude (H-NIQ) were used as covariates in the data analysis to exclude the influence of intelligence.

Iowa Gambling Task

Results of deck selections

A generalized linear mixed effects model was constructed to analyze the number of cards selected. The model contained one between-participants factor (deaf group vs. hearing group) and two within-participants factors (deck, block) as fixed factors, two covariates (H-NIQ, RIQ), and a random factor (participants). The main effect of deck was significant ($F = 130.91$, $p < .001$), and parameter estimates showed that all participants were less likely to choose Decks A and C, which means that they preferred a low frequency of losses; there were no main effects of group ($F < .01$, $p > .05$) or block ($F < .01$, $p > .05$). The interaction between group and deck was significant ($F = 4.89$, $p < .01$), which showed that deaf students chose Deck B more often. Deck had a significant interaction with block ($F = 2.96$, $p < .001$), which revealed that all participants selected more cards from Decks A, B, and C than from Deck D in Block 1. The interaction between group and block was not significant ($F < .01$, $p > .05$). In addition, there was a significant interaction among deck, group, and block ($F = 2.24$, $p < .01$), indicating that deaf students were more likely to choose Deck D cards in Block 1 (see Tables 3 and 4).

Further, four repeated-measures analyses of covariance were performed on the Iowa Gambling Task, with the number of cards selected from Decks A, B, C, and D in each block as the dependent variable, respectively, each with two covariates (H-NIQ, RIQ), one between-participants factor (deaf group vs. hearing group), and one within-participants factor (block). The main effect of group for Deck D was significant ($F = 5.22$, $p < .05$, $\eta^2 = .07$); the hearing group selected more Deck D cards than the deaf group. There were no other main effects ($Fs < .01$, $ps > .05$). The interactions between group and block were significant for Deck B ($F = 3.21$, $p < .05$, $\eta^2 = .05$) and Deck D ($F = 2.65$, $p < .05$, $\eta^2 = .04$). Simple effect analysis showed the deaf students chose

Table 3 Means and standard deviations in the Iowa Gambling Task

		Deaf group ($n = 36$)	Hearing group ($n = 36$)
Block 1	Deck A	4.75 (1.71)	4.33 (2.27)
	Deck B	5.58 (2.56)	6.97 (3.71)
	Deck C	4.81 (1.69)	4.11 (2.03)
	Deck D	4.86 (2.57)	4.58 (1.99)
Block 2	Deck A	3.75 (2.05)	3.33 (1.80)
	Deck B	7.03 (4.05)	7.03 (3.41)
	Deck C	4.22 (2.19)	3.75 (2.26)
	Deck D	5.00 (3.03)	5.89 (2.93)
Block 3	Deck A	3.36 (2.1)	3.28 (1.95)
	Deck B	7.89 (3.73)	6.28 (3.06)
	Deck C	4.03 (2.16)	3.78 (2.33)
	Deck D	4.72 (2.61)	6.67 (3.19)
Block 4	Deck A	2.94 (1.76)	2.92 (1.86)
	Deck B	7.78 (3.31)	7.06 (3.44)
	Deck C	4.08 (2.23)	4.11 (2.92)
	Deck D	5.19 (2.64)	5.92 (2.20)
Block 5	Deck A	2.94 (2.07)	3.50 (2.50)
	Deck B	8.50 (3.26)	6.69 (3.45)
	Deck C	3.61 (2.13)	3.75 (2.57)
	Deck D	4.94 (2.57)	6.06 (2.60)

Deck B cards in the third block ($F = 7.86$, $p < .01$, $\eta^2 = .10$) more often than the hearing group, while they chose Deck D cards ($F = 11.30$, $p < .01$, $\eta^2 = .14$) less frequently in the third block. The fact that the deaf students chose more cards from Deck B, while the hearing group selected more cards from Deck D, indicates that the deaf group selected more disadvantaged cards compared with the hearing group (see Figure 3).

Results of loss frequency selections

A generalized linear mixed effects model was constructed to analyze the number of selections made from decks with different frequencies of losses in each block, with loss frequency, group, and block as fixed factors, H-NIQ and RIQ as covariates, and participants as a random factor. As shown in Table 5, the main effect of loss frequency was significant ($F = 468.86$, $p < .001$): decks with infrequent losses were chosen significantly more often than those with frequent losses. There were no main effects of group or block ($Fs < .01$, $ps > .05$). Loss frequency interacted significantly with block ($F = 11.203$, $p < .001$): decks with frequent losses were chosen significantly more often than those with infrequent losses in Block 1. The interactions between group and loss frequency, between group and block, and among loss frequency, group, and block were not significant ($Fs < 2.07$, $ps > .05$).

Task understanding

According to Bechara et al. (1994), Decks A and B are the "bad decks," while Decks C and D are the "good decks." After they had performed 100 selections in the Iowa Gambling Task, the participants were asked to rank the decks according to their evaluation of the decks from good to bad. For each deck, we compared the rank in two groups with a chi-squared test. The results revealed that evaluation of each deck was independent of participant group (for Deck A, $\chi^2 = .82$, $p = .85$; for Deck B, $\chi^2 = 3.56$, $p = .31$; for Deck C, $\chi^2 = 2.52$, $p = .47$; and for Deck D, $\chi^2 = 1.83$, $p = .61$). Moreover, if a participant chose both Decks C and D as good decks, they scored 2 points; if they chose either Deck C or Deck D as a good deck, they scored 1 point; and if they

Table 4 Group preference estimation of participants (all blocks)

Fixed effects	Estimate	SE	T	F
Deck selection				130.91***
Deck A—Deck D	−2.56	.62	−4.10***	
Deck C—Deck D	−2.31	.62	−3.70***	
Deck selection * Group				4.89**
The selection of Deck B of deaf group—The selection of Deck D of deaf group	2.92	.88	3.31**	
Deck selection * block				2.88**
The selection of Deck A in Block 1—The selection of Deck D in Block 1	2.31	.88	2.61**	
The selection of Deck B in Block 1—The selection of Deck D in Block 1	1.75	.88	1.98*	
The selection of Deck C in Block 1—The selection of Deck D in Block 1	1.83	.88	2.08*	
Deck selection * Group * block				2.24**
The selection of Deck B of deaf group in Block 1—The selection of Deck D of deaf group in Block 1	−4.58	1.24	−3.67***	

*.05 > p > .01, **.01 > p > .001, ***p < .001.

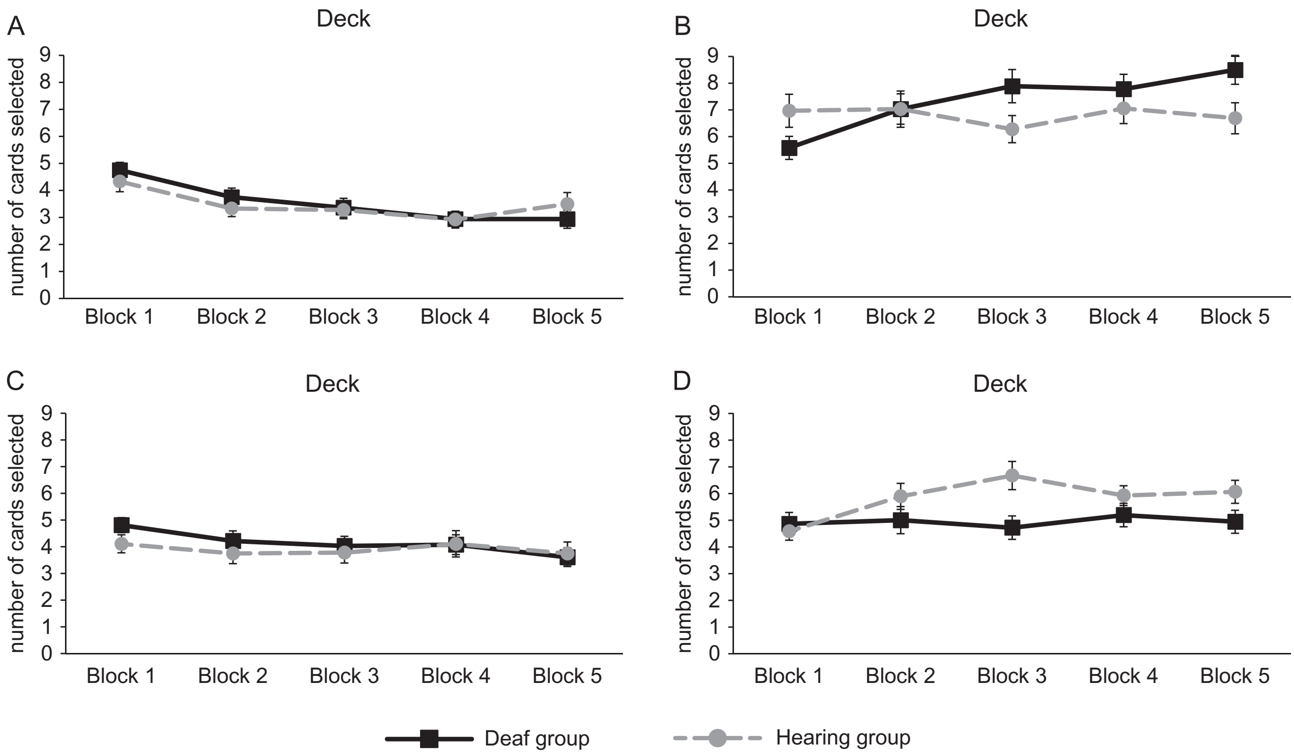

Figure 3 Number of cards selected in blocks during the Iowa Gambling Task. Mean number of cards (Mean ± SEM) selected from Decks A, B, C, and D for deaf and hearing adolescents, graphed as a function of trial block.

Table 5 Loss frequency preference estimation (all blocks)

Fixed effects	Estimate	SE	T	F
Loss frequency				468.86***
High-loss frequency—Low-loss frequency	−5.50	.72	−7.64***	
Loss frequency*block				2.07**
High-loss frequency in block 1—Low-loss frequency in block 1	2.39	1.02	2.34*	

*.05 > p > .01, **.01 > p > .001, ***p < .001.

chose neither Deck C nor Deck D as a good deck, they scored 0 points. Application of the chi-squared test revealed no evidence of association between task understanding and participant group ($\chi^2 = .83$, $p = .66$).

Game of Dice Task

For analysis of the Game of Dice Task, a repeated-measures analysis of covariance was performed, with the frequency of choices of each separate alternative (one single number, two

Table 6 Means and standard deviations in the Game of Dice Task

	Deaf group (n = 36)	Hearing group (n = 36)
One number	6.47 (5.25)	1.94 (2.67)
Two numbers	3.22 (2.29)	3.47 (3.69)
Three numbers	2.72 (1.92)	4.83 (2.94)
Four numbers	5.58 (4.98)	7.75 (5.38)

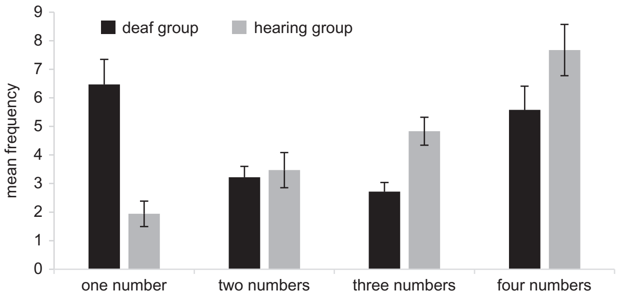

Figure 4 Number of choices in each single alternative. Mean frequency of each single alternative (Mean ± SEM) in the Game of Dice Task of the deaf group and the hearing group.

numbers together, three numbers together, and four numbers together) as the dependent variable. The independent variables included the following four factors, the group (between-participants factor), the option (within-participants factor), which was controlled by the experimenter, and the H-NIQ and RIQ were covariates. As shown in Table 6 and Figure 4, there were no main effects of option (F = 2.36, p = .08, η^2 = .03) or group (F < 0.01, p = 1.00, η^2 < .01), but the interaction between option and group was significant (F = 3.58, p < .05, η^2 = .05). Further simple effects analysis showed a significant difference in the frequency of choosing a single number (F = 6.96, p < .05, η^2 = .09) between the deaf group and the hearing group. A least significant difference post hoc test revealed that the deaf group was significantly more likely to choose one number than the hearing group. Furthermore, there were significant differences among different options within the deaf group (F = 5.97, p < .01), and a least significant difference post hoc test revealed the deaf students chose a single number more frequently than two and three numbers. In contrast, although there were also significant differences among different options in the hearing group (F = 11.05, p < .001), a least significant difference post hoc test revealed that in this group, the four-number option was chosen significantly more often than the other options.

Additionally, frequency of the riskiest alternative (one single number) was analyzed, as its high frequency indicates disadvantageous decision-making (Brand & Schiebener, 2013; Brand, 2008). An analysis of covariance with the frequency of a single number as the dependent variable, group as between factor, and H-NIQ and RIQ as covariates revealed the deaf adolescents chose the single number alternative more often than their hearing peers (F = 6.96, p < .05, η^2 = .09).

Discussion

The primary finding from the present study is that deaf adolescents showed a preference for high-risk options compared to the hearing group in both the Iowa Gambling Task and the Game of Dice Task, which might be associated with differences in inhibition control and utilization of feedback.

The deaf adolescents showed a preference for Deck B in the Iowa Gambling Task, which offered high immediate gain but higher future loss. The choice of cards from Deck B in the Iowa Gambling Task is an important indicator of impulse inhibition (Lin, Chiu, Lee, & Hsieh, 2007). Meanwhile, we found that deaf adolescents showed a preference for a single number in the Game of Dice Task, which is a option with high potential gain but a higher chance of loss. As suggested in many previous studies, deaf children show differences in executive function, including inhibition control, as measured by both scales and behavioral tasks (Figueras et al., 2008; Hintermair, 2013; Kronenberger et al., 2014), and executive function plays an important role in many decision-making behaviors. Executive function, including inhibition control, is associated with performance in the Iowa Gambling Task. For instance, individuals with damage to the dorsolateral prefrontal cortex showed impaired executive function and a preference for disadvantageous selections (Manes et al., 2002; Ouerchefani, Ouerchefani, Allain, Ben Rejeb, & Le Gall, 2017). The Game of Dice Task was designed to explore the role of executive function in decision-making (Brand, Fujiwara, et al., 2005; Gathmann, Pawlikowski, Scholer, & Brand, 2014; Schiebener, Garcia-Arias, Garcia-Villamisar, Cabanyes-Truffino, & Brand, 2015), and that participants with decreased executive functioning make more risky choices has been demonstrated in children, adolescents (Schiebener et al., 2015), and older adults (Brand & Schiebener, 2013). In fact, the executive control ability measured by the Color-Word Interference Test and Trail Making Test (Part B), which is used to assess psychomotor control and loads particularly on inhibitory control and shifting, is a key predictor of decision-making in the Game of Dice Task (Schiebener et al., 2014). In the present study, the preferences of deaf adolescents in both tasks were all risky options with greater potential gain and negative mathematical expected value. The results might indicate that deaf adolescents were different from their hearing peers with regard to inhibiting the tendency to choose immediate large rewards and taking the larger loss into account. Inhibition control, as well as working memory and cognitive flexibility, is a component of executive function (Diamond, 2013; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000) that influences decision-making behavior. Thus, the performance of deaf adolescents on the Iowa Gambling Task and the Game of Dice Task might be associated with differences in inhibition control.

At the same time, another shared feature between Deck B and the option of a single number is the greater potential loss in the future, and this preference might reveal that deaf students could not advantageously utilize feedback. Brand et al. (2006) proposed that decision-making behavior under risk is regulated both by the available information about probabilities prior to the decision and by the feedback provided by loss or gain after the decision, while decision-making under ambiguity also requires the participants to learn the implicit rules through feedback from winning or losing. In the Iowa Gambling Task, individuals learn to avoid the bad options and prefer the good alternatives implicitly by processing feedback of previous decisions (Bechara, Damasio, Tranel, & Damasio, 1997). Moreover, patients with Urbach-Wiethe disease showed decreased skin conductance responses during the Game of Dice Task compared to healthy controls (Brand, Grabenhorst, et al., 2007), and prior research has reported a difference in the capacity to advantageously utilize feedback in patients who show performance deficits in the Game of Dice Task (Euteneuer et al., 2009; Svaldi et al., 2012). Thus, feedback is an important source of information in decision-making tasks, and the performance of deaf adolescents might be related to their capacity to advantageously utilize feedback.

Working memory, as a component of executive function, also might influence performance in decision-making, and there is evidence that deaf children's visual working memory differs from that of hearing children (Lopez-Crespo, Daza, & Mendez-Lopez, 2012). However, working memory may not be the cause of differences between the deaf and hearing groups in the current study. The demands on working memory are higher in the Iowa Gambling Task than in the Game of Dice Task, because the rules of the former are not clear to the participant. However, the deaf adolescents exhibited similar preferences in both tasks, which indicates that working memory, or the clarity of rules relating to risk, may not be the main cause of decision-making variance in deaf adolescents. Additionally, our data on participants' understanding of the Iowa Gambling Task showed that there was no difference between the deaf group and the hearing group. Another evidence shows that all participants were less likely to choose cards from Deck A or C in the Iowa Gambling Task, which means they were able to harness working memory enough to produce sensitivity to the frequency of losses. Participants preferred infrequent losses, which also indicates that working memory does not reasonably explain the differences between the deaf and hearing groups.

At the same time, the conclusions drawn about decision-making in deaf adolescents should be considered with caution. Our data only reveal that deaf adolescents exhibited a preference for risky decision-making in both tasks—the cards from Deck B in the Iowa Gambling Task and single number in the Game of Dice Task are high-gain and high-loss options with negative expected value. Therefore, it can be concluded that deaf adolescents seem to prefer short-term and immediate large returns. This may be associated with their executive function, especially inhibitory control, and the capacity to advantageously utilize feedback. However, the preference for risk in deaf adolescents is also restricted by the total number of selections; that is, if they selected more risky options, the remaining safe options are definitely selected less frequently than hearing peers. Additionally, all the participants in this study were adolescents, whose performance in the gambling task has been found not to be identical to that of adults in some research (Cauffman et al., 2010; Smith, Xiao, & Bechara, 2012). Since participants' performance in this study was also influenced by their stage of development, further research should explore the performance of deaf adults.

Conclusion

Our research has revealed that adolescents with profound hearing loss showed a preference for high gains without regard for the attendant potential risks in gambling tasks with transparently determined rules (Game of Dice Task) and with rule ambiguity (Iowa Gambling Task). Additionally, they showed a preference for infrequent losses consistent with hearing participants in the Iowa Gambling Task. However, this study only explored the decision-making behavior of deaf adolescents; further neurophysiological studies are needed to reveal the characteristics of the decision-making behavior of deaf adolescents, and the decision-making performance of adults is also worth exploring.

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Conflict of Interest

No conflicts of interest were reported.

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