



Inflexible eye fixation pattern in schizophrenia affecting decision-making on daily life



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ABSTRACT

Patients with schizophrenia have difficulties in real life due to impairment in ability to make decisions. The purpose of this study was to elucidate the relationship between impaired decision-making processes with real life stimuli and abnormal eye gaze patterns in patients with schizophrenia. Each of 23 patients with schizophrenia and 23 healthy controls performed an apparel purchase decision task including the influencing factors such as preference, fit, and price, during which the eye gaze was traced. Fixation time and fixation time ratio on areas of interest, which were set for participant faces and clothing, were compared between the two groups. Compared with controls, patients made purchase decisions at a higher rate and showed significantly shorter fixation time on clothing in the preference, fit, and price phases and on faces in the purchase phase. Fixation time ratio of face over clothing did not change over purchase decisions in patients, whereas controls showed significantly higher fixation time ratio in not-to-buy decisions than in to-buy decisions. These results suggest that aberrant decision-making behaviors in patients with schizophrenia are closely related to inflexible visual information gathering patterns because they apportion the same amount of attention to objects regardless of purchase intention.

1. Introduction

Decision-making refers to a series of complex processes or perception and integration of information from a surrounding environment with a specific purpose and motive, evaluation of risks and rewards, and the taking of action based on this evaluation, which requires extensive functions from sensorimotor to high cognitive function (Heekeren et al., 2008; Shadlen and Kiani, 2013). In schizophrenia, positive symptoms such as hallucinations and delusions cause impairment in decision-making abilities of patients with the illness due to jump-to-perception and jump-to-conclusion biases (Bristow et al., 2014). Even once positive symptoms are relieved via psychopharmacological treatment, negative symptoms such as blunted affect, avolition, anhedonia, and asociality affect decision-making processes, causing persistent problems (Lee et al., 2015; Radua et al., 2015; Wang et al., 2015; Huang et al., 2016). Patients with schizophrenia have a tendency to be reluctant to get involved in tasks that are physically or cognitively more demanding due to negative symptoms (Gold et al., 2013; Barch et al., 2014; Wolf et al., 2014; Hartmann et al., 2015; Treadway et al., 2015). In social decision-making tasks such as

Ultimatum game, aberrant behaviors such as greater acceptance of unfair offers and greater rejection of fair offers have been observed in patients with schizophrenia, departing from the social norms of the public (Csukly et al., 2011; Wischniewski and Brune, 2011; de la Asuncion et al., 2015).

Despite previous studies using gambling tasks, behavioral results have revealed only the consequences of complex decision-making processes. Eye tracking stands to be useful for comprehending decision-making process via visual information processing (Mele and Federici, 2012). People tend to focus their attention according to their intentions (O'Malley and Besner, 2014), and eye gaze reflects cognitive abilities, such as attention and scene perception (Rayner, 2009). Therefore, eye tracking has been used as a tool to intuitively visualize the flow of attention during processes of decision-making. For example, the relationship between eye gaze pattern during decision-making and features of stimuli presentation has been explored in previous researches (Morii et al., 2017; Starke and Baber, 2018). The gathering of information through eye gaze pattern and its effect on decision-making has also been conducted in previous studies with gambling tasks (Kwak et al., 2015; Zommaro et al., 2018).

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Several attempts using eye tracking have been made to understand visual information processing in patients with schizophrenia. A representative example is slow eye movement and limited, localized searching for visual information (Deleue and Boucart, 2012). Another example is aberrant visual exploration in the processing of social signals such as face expressions (Choi et al., 2010; Beedie et al., 2011; Jang et al., 2016; Nikolaides et al., 2016). Some researchers have suggested that the processing of gaze information has the potential to be an endophenotype of psychosis (Lencer et al., 2015; Thibaut et al., 2015; Caldani et al., 2017). In addition, it has been found that characteristic limited visual searching in patients with schizophrenia is related to severity of negative symptoms and difficulty with social interaction (Kojima et al., 2001; Choi et al., 2010). Meanwhile, diminished capacity to experience pleasure or anhedonia due to negative symptoms in patients with schizophrenia is related to a deficit in emotion-based learning, as shown in research based on the Iowa gambling task (Matsuzawa et al., 2015), and reflects a deficit in value judgment and impaired value representation during decision-making (Strauss et al., 2018). Taken together, these findings indicate that gathering gaze information through the eye tracking methodology seems appropriate and necessary to determine the effects on impairment in decision-making processes and the association with anhedonia in patients with schizophrenia. This information not only contributes to understanding the problems of social cognitive deficits in patients' daily lives, but also has direct therapeutic implications such as use as a material for remediate the deficits in a comprehensive training program (Toh et al., 2011).

Most previous eye tracking studies in schizophrenia have been limited to findings from highly refined stimuli of laboratory setting (as opposed to real life stimuli). In fact, eye tracking has been utilized to explore cognitive or emotional effects of various stimuli on people in real life. For instance, previous studies in marketing have examined the contributions of gaze to product purchase decision-making in consumers (Atalay et al., 2012; Peschel and Orquin, 2013; Gidlof et al., 2017). Because a decline in the decision-making capacity of patients with schizophrenia impacts many areas of their lives, an eye tracking study using a decision-making task as a proxy for real life is necessary. Given that various influencing factors are important in decision-making processes during apparel purchasing behaviors (Sproles and Kendall, 1986; Eckman et al., 1990; Wesley et al., 2006), pertinent factors must be included in the task.

The purpose of this study was to elucidate the relationship between decision-making processes with real life stimuli and eye gaze patterns in patients with schizophrenia. For this purpose, we measured the eye gaze during an apparel purchase decision task including influencing factors such as preference, fit, and price, and compared the task performances between patients and healthy controls. We hypothesized that

patients would show irrational decision-making during the purchasing behaviors because negative symptoms induce aberrant use of influencing factors and because a problem of gaze distribution in the process of gathering visual information might be involved.

2. Methods

2.1. Participants

Participants in this study comprised 26 patients with schizophrenia and 23 healthy controls. All patients were recruited from an open advertisement in a psychiatric outpatient clinic. Healthy controls with neither present psychiatric conditions nor a past psychiatric history were recruited from an open internet advertisement. The inclusive diagnosis of schizophrenia in the patient group and the exclusion of psychiatric disorders in the control group were made by a trained psychiatrist using the Structural Clinical Interview for the Diagnostic and Statistical Manual of Mental Disorders, 4th Edition (Spitzer et al., 1994). Exclusion criteria were a presence of significant neurological disorders, substance use disorders, or intellectual disability. Any participants with severe ophthalmologic disease who were unable to conduct the task were also excluded. Because one patient did not respond too much and 2 patients had too many artificial signals in the acquisition of eye tracking data, a total of 3 patients' data were excluded from the analysis and data from 23 patients were used. All patients were taking atypical antipsychotics, and the mean chlorpromazine equivalent dose (Gardner et al., 2010) was 474.64 ± 341.63 mg. This study was approved by the Institutional Review Board of Yonsei University Gangnam Severance Hospital. Informed consent was obtained from all participants who were given a cover story including the study purpose, potential discomforts and benefits, participation and withdrawal, and confidentiality.

2.2. Clinical measurements

Socioeconomic status was assessed with a self-rating ordinal scale (Leckie and Gallagher, 2011) ranging from 1 to 5 for income, education, and occupation status. For statistical significance, scores of 1 were described as high, scores of 2 and 3 were moderate, and scores of 4 and 5 were low. Intellectual quotient and visuospatial memory function were measured using the Raven's Standard Progressive Matrices (SPM) (Raven, 2000) and Rey complex figure test (RCFT) (Meyers and Meyers, 1995), respectively. The Physical and Social Anhedonia Scales (Chapman et al., 1976) were used to measure level of anhedonia. The severity of symptoms in patients with schizophrenia was evaluated using the Positive and Negative Syndrome Scale (PANSS) (Kay et al., 1987).

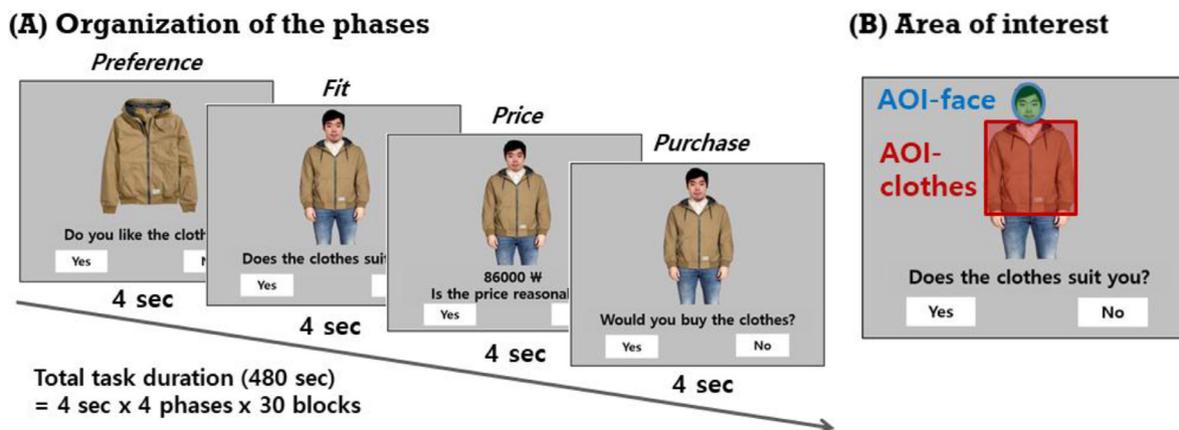


Fig. 1. An example of the task blocks in the apparel purchase decision task (A) and the area of interest (AOI) on the visual stimuli in the fit phase (B).

2.3. Behavioral task

As shown in Fig. 1A, we developed an apparel purchase decision task in which 30 different clothing items (10 formal, 10 casual, and 10 sporty clothing items) were shown to participants sequentially in random order. Males were presented with men's clothing, and females were presented with women's clothing. The clothing used as stimuli were limited to a set of items that could be presented adjacent to a participant's face, such as shirts, jacket, or dresses, and were edited from images on online shopping sites. The block allocated to each clothing item consisted of four 4-second phases including preference, fit, price, and purchase, with no interval in fixed order. In the first preference phase, only the clothing of the clothes was presented with the question, "Do you like the clothes?" In the following phases, clothing stimuli were presented in combination with participant faces (all participants were photographed before the experiment). The questions were "Do the clothes suit you?" in the fit phase, "Is the price reasonable?" in the price phase, and "Would you buy the clothes?" in the purchase phase. In the price phase, a median of prices suggested by 10 non-schizophrenic volunteers in a preliminary test prior to this study was displayed as the price of each clothing item. In all phases, participants were instructed to respond to each question by pressing a button for yes or no, and not to react too late to the stimuli that had already passed if the stimuli had not responded within 4 s.

2.4. Eye gaze recording and data processing

The experiment was carried out in a laboratory with simple facilities and black walls to prevent distracting stimuli. Recording was performed using a SensoMotoric Instrument (SMI, Boston, MA, USA) eye tracking recording system with an infrared camera Remote Eye Tracking Device 5 (RED5) and software including Experiment Center 3.0 for stimulus presentation, SMI iView for eye gaze data processing, and SMI BeGaze program for extraction of eye gaze data. To minimize participant head movements and stably detect the eye movements, a monitor for presenting the stimuli (17-inch with 4:3 aspect ratio; LG electronics., model number: 17MB15P) was placed 70 cm from the eyes of participants, and participants' chins were fixed on a mount. Before the main task, participants were told to fix their gaze upon several circles to calibrate and validate their eye movements.

The area of interest (AOI) for eye gaze data analysis was defined as the face part of the circle (AOI-face) and the clothing part of the rectangle (AOI-clothes) as shown in Fig. 1B. Considering the characteristics of the stimuli, we defined only the clothing part in the preference phase and both AOIs in the other three phases of the task, and we measured fixation time for each AOI. Eye fixation refers to the state when the participant fixed his or her gaze for more than 80 ms in an area within 100 pixels, and fixation time indicates the sum of the time during which the gaze was fixed on the AOI. Because 30 different stimuli were presented during the task, the resulting fixation time was defined as the average of fixation times calculated for each stimulus.

2.5. Statistical analysis

Demographic and clinical characteristics were compared using chi-square tests for categorical and ordinal variables and independent sample *t*-tests for continuous variables between patients and controls. Behavioral responses (the rate of "yes" answers, missing rate, and response time) were compared using independent sample *t*-test. Correlation analysis was conducted to find out a relationship between behavioral responses and clinical variables.

To grasp the overall pattern of decision-making in our tasks with repetitive blocks, an extended tool of generalized linear modeling, a generalized estimating equation (GEE), was applied to analyze the influence of decisions in the first three phases of the task on decision in the final purchase phase of the task. The influence of preference, fit, and

price on a participant's final purchase decision was expressed as an odds ratio. If the odds ratio of an influencing factor was higher or lower than 1, we considered it a positive answer to the question related to the factor in comparison to a negative answer, leading to an increase or decrease, respectively, in the probability of a positive answer in the final purchase decision. GEE was also used to compare the effects of each influencing factor on final purchase decisions between the two groups. In this between-group analysis, if the odds ratio of an influencing factor was higher or lower than 1, we determined that the effect of the factor on decision-making in patients was larger or smaller, respectively, than the effect of the factor on decision-making in controls.

Group differences in fixation time were assessed in each AOI using independent sample *t*-test, in which the size of AOI was controlled. Considering the importance of final purchase decision, fixation time ratio of the AOI-face over AOI-clothes (F/C fixation time ratio) during the to-buy or not-to-buy decisions in the purchase phase was calculated in each block supposing that each block was independent, and group differences were assessed using two-by-two analysis of variance (ANOVA) and post-hoc *t*-tests. Partial correlation analysis was used to examine the association of F/C fixation time ratio with clinical variables and decision patterns. All eye gaze data were analyzed adjusting for different sizes of clothing. All behavioral and eye gaze data were used without excluding outliers, whereas missing values were excluded in the analysis.

3. Results

3.1. Demographic and clinical characteristics

Table 1 summarizes the demographic and clinical data of patients and controls. There were no significant differences in age, sex, and social economic status between the two groups of participants. The group differences in cognitive measurements, including the raw scores of the Raven's SPM and subscale scores of the RCFT, were also insignificant. However, the scores of the Physical and Social Anhedonia Scales were significantly higher in patients than in controls (physical: $t_{44} = 3.888, p < 0.001$; social: $t_{44} = 3.271, p = 0.002$)₄₄.

3.2. Behavioral responses

As shown in Table 2, the rate of "yes" answers did not differ in the preference, fit, and price phases of the task between patients and controls. In the purchase phase, however, the rate was significantly higher in patients than in controls ($t_{44} = 2.199, p = 0.033$). In the preference, fit, and price phases, the missing rates were significantly higher in patients ($t_{44} = 2.601, p = 0.013$; $t_{44} = 2.465, p = 0.018$; and $t_{44} = 2.805, p = 0.007$, respectively) than in controls, but not in the purchase phase. Response time showed no significant group difference in all phases.

In correlations between behavioral responses, patients showed significant positive correlations between missing rate and response time in the preference, fit, and price phases ($r = 0.306, p = 0.039$; $r = 0.374, p = 0.01$; and $r = 0.481, p = 0.001$, respectively). In correlations of behavioral responses with demographic variables or with the PANSS subscale scores and Physical/Social Anhedonia Scale scores in patients, the only significant result in patients was negative correlation between response time and the Physical Anhedonia Scale scores ($r = -0.458, p = 0.028$) in the price phase. In correlations between behavioral responses and demographic variables, there was no significant result ($r < 0.384, p > 0.07$).

Table 3 depicts the odds ratios of the three influencing factors in the final purchase decision of the task. The odds ratios of preference, fit, and price for purchase decision were all statistically significant in patients [3.260 ($p = 0.006$), 12.491 ($p < 0.001$), and 14.380 ($p < 0.001$), respectively] and controls [11.974, 17.631, and 24.224, respectively; $p < 0.001$ in all]. The group difference in the odds ratio without and with

Table 1
Demographic and clinical characteristics of participants.

	Schizophrenia (n = 23)	Control (n = 23)		
Categorical variables	n (%)	n (%)	χ^2	p
Sex				
Male	11 (47.8%)	11 (47.8%)	<0.001	1.000
Female	12 (52.2%)	12 (52.2%)		
Socio-economic status ^a				
Low	6 (26.1%)	7 (30.4%)	3.210	0.201
Medium	14 (60.9%)	16 (69.6%)		
High	3 (13.0%)	0 (0.0%)		
Continuous variables	Mean \pm SD	Mean \pm SD	t	p
Age (years)	33.35 \pm 5.98	34.04 \pm 5.36	0.415	0.680
Raven's SPM	44.48 \pm 10.67	47.61 \pm 7.25	-1.164	0.251
Rey Complex Figure Test				
Copy	32.67 \pm 4.17	31.95 \pm 5.30	0.507	0.615
3-min immediate recall	16.39 \pm 8.29	20.07 \pm 6.69	-1.632	0.110
20-min delayed recall	15.59 \pm 8.35	19.70 \pm 7.53	-1.735	0.090
Physical Anhedonia Scale	20.96 \pm 8.39	13.09 \pm 4.89	3.888	<0.001
Social Anhedonia Scale	12.70 \pm 6.60	7.43 \pm 3.99	3.271	0.002
PANSS				
Positive	16.87 \pm 4.29	-	-	-
Negative	19.61 \pm 4.96	-	-	-
General	31.65 \pm 6.41	-	-	-
Chlorpromazine equivalent dose (mg)	474.64 \pm 341.63	-	-	-

SD, standard deviation; SPM, Standard Progressive Matrices; PANSS, Positive and Negative Syndrome Scale.

^a High, medium, and low mean scores of 1, 2 and 3, and 4 and 5, respectively, in the socioeconomic status assessed with a self-rating ordinal scale (Leckie and Gallagher, 2011).

Table 2
Behavioral responses (mean \pm standard deviation) in each phase of preference, fit, price, and purchase in the schizophrenia and control groups.

Phase	Schizophrenia (n = 23)	Control (n = 23)	t	p
Rate of "yes" answers				
Preference	0.478 \pm 0.168	0.397 \pm 0.226	1.368	0.178
Fit	0.490 \pm 0.174	0.394 \pm 0.238	1.556	0.127
Price	0.423 \pm 0.168	0.335 \pm 0.176	1.741	0.089
Purchase	0.341 \pm 0.160	0.236 \pm 0.162	2.199	0.033
Missing rate				
Preference	0.057 \pm 0.060	0.020 \pm 0.030	2.601	0.013
Fit	0.045 \pm 0.051	0.016 \pm 0.024	2.465	0.018
Price	0.057 \pm 0.062	0.017 \pm 0.026	2.805	0.007
Purchase	0.023 \pm 0.040	0.007 \pm 0.017	1.774	0.083
Response time (ms)				
Preference	1668.45 \pm 261.91	1608.89 \pm 279.97	0.748	0.459
Fit	1559.13 \pm 313.85	1446.33 \pm 280.37	1.285	0.205
Price	1441.42 \pm 291.33	1404.56 \pm 273.69	0.442	0.660
Purchase	1069.82 \pm 272.46	953.91 \pm 212.18	1.610	0.115

an adjustment for delayed memory scores from the RCFT was significant in the preference phase [0.272 ($p = 0.015$) in both], but not in the fit and price phases of the task.

3.3. Eye gaze data

For fixation time on the face, the only group significant difference was in the purchase phase; patients showed significantly shorter fixation time than controls (71.75 \pm 72.65 ms and 166.39 \pm 147.72 ms, respectively, $t_{44} = -2.757$, $p = 0.005$). Significant group differences in fixation time on clothing were also observed; patients showed significantly shorter fixation time in the first three phases than controls (preference: 972.91 \pm 523.70 ms and 1327.93 \pm 458.28 ms, respectively, $t_{44} = -2.793$, $p = 0.002$; fit: 539.46 \pm 425.95 ms and 912.09 \pm 410.37 ms, respectively, $t_{44} = -2.447$, $p = 0.009$; and price: 731.54 \pm 603.74 ms and 991.39 \pm 421.76 ms, respectively, $t_{44} = -3.021$, $p = 0.001$), but not in the purchase phase (Fig. 2).

In order to investigate the eye gaze on the AOI-face over AOI-

Table 3
The odds ratios and 95% confidence interval (CI) for the influencing factors (preference, fit, and price) in the purchase decision in each group and in patients compared to controls.

Variable	Odds ratios	95% CI	p
<i>Schizophrenia</i>			
Preference	3.260	1.409 - 7.543	0.006
Fit	12.491	4.988 - 31.281	<0.001
Price	14.380	6.755 - 30.614	<0.001
<i>Control</i>			
Preference	11.974	6.335 - 22.634	<0.001
Fit	17.631	7.251 - 42.873	<0.001
Price	24.224	12.130 - 48.374	<0.001
<i>Schizophrenia compared to control</i>			
<No adjustment>			
Preference	0.272	0.095 - 0.780	0.015
Fit	0.708	0.197 - 2.542	0.597
Price	0.594	0.213 - 1.653	0.318
<Adjustment for delayed memory scores>			
Preference	0.272	0.095 - 0.777	0.015
Fit	0.705	0.195 - 2.542	0.593
Price	0.612	0.224 - 1.671	0.338

clothes, F/C fixation time ratios were compared according to responses during the purchase phase in patients and controls. Fig. 3 presents the reciprocal of this ratio for convenience of explanation. F/C fixation time ratio showed no main effects of group ($F_{1,1077} = 0.673$, $p = 0.558$) or decision ($F_{1,1077} = 0.728$, $p = 0.552$), but the group \times decision interaction effect was significant ($F_{1,1077} = 187.654$, $p = 0.046$). Patients showed no significant differences in F/C fixation time ratios between to-buy and not-to-buy decisions (0.184 \pm 0.107 and 0.158 \pm 0.078, respectively), whereas control participants showed significantly lower F/C fixation time ratio in to-buy decisions than in not-to-buy decisions (0.155 \pm 0.113 and 0.475 \pm 0.064, respectively) ($t_{608} = -3.388$, $p = 0.001$). F/C fixation time ratios in to-buy decisions of participants were not significantly different between the two groups, whereas F/C fixation time ratios in not-to-buy decisions of participants were significantly lower in patients than in controls ($t_{773} = -3.108$, $p = 0.002$). In each group, fixation time on the AOI-face or AOI-clothes

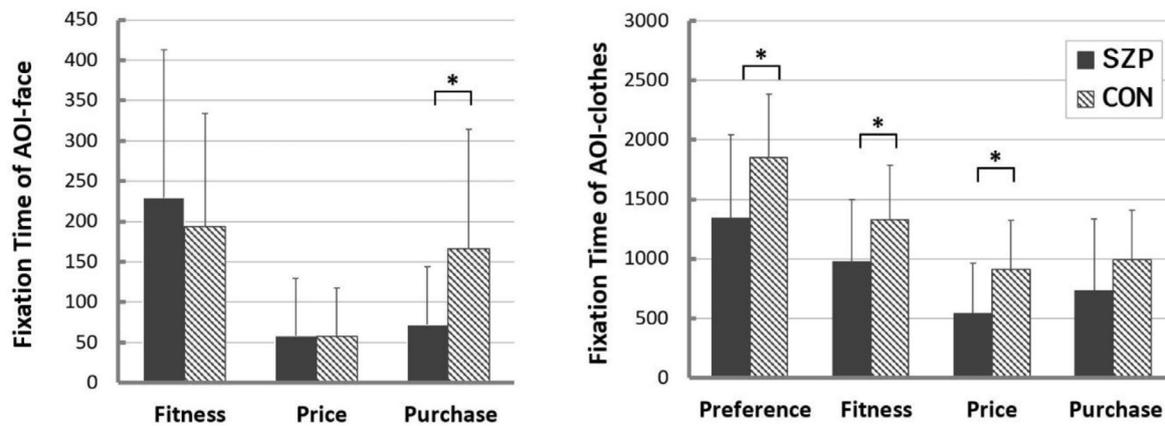


Fig. 2. Mean ± standard deviation of fixation time (ms) on the face and the clothes in patients with schizophrenia (SZP) and controls (CON). **p* [corrected for the size of the areas of interest (AOI) for the face and clothes] < 0.01.

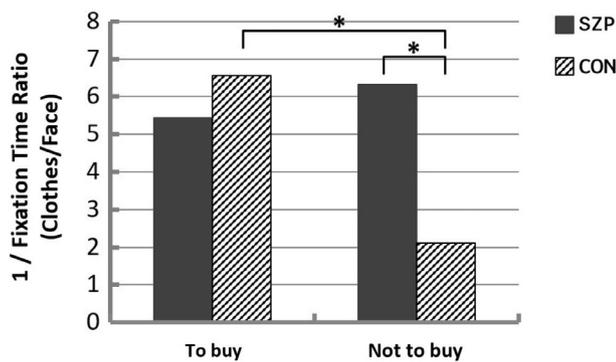


Fig. 3. The reciprocal of fixation time ratio (face over clothes) according to responses during the purchase phase in patients with schizophrenia (SZP) and controls (CON). **p* < 0.01.

and F/C fixation time ratios in each phase were not significantly correlated with the behavioral responses in the phase or with any clinical variables ($r < 0.391, p > 0.088$).

4. Discussion

In this study for investigating the relationship between decision-making processes in real life situations and eye gaze patterns using the apparel purchase decision task, we sought to clarify irrational decision-making of patients with schizophrenia during the purchasing behaviors due to negative symptoms and ineffective visual information gathering. The primary outcome to be mentioned first is that patients with schizophrenia in our study showed shorter fixation time in several phases. Shorter fixation time in patients was found only in the purchase phase for the AOI-face and in all phases except the purchase phase for the AOI-clothes. These results are consistent with the findings of previous reports in which patients with schizophrenia show decreased eye fixation during the performance of theme-identification tasks (Oh et al., 2014) and natural scan tasks (Bestelmeyer et al., 2006).

In terms of behavioral results, in comparison to controls, patients showed no differences in decisions regarding preference, fit and price of clothing, but tended to purchase more clothing items. In both groups, decisions regarding preference, fit, and price of clothing had significant effects on purchase decisions, but preference was shown to be less important in the final purchase decisions of patients in comparison to controls. The problem of visuospatial memory or cognitive processing speed in patients does not sufficiently explain this result, because adjustment for delayed recall scores of the RCFT and response time during the task were shown to make no group difference. Although patients

were more inattentive than controls as seen from the difference in the missing rate between the two groups, the problem of attention to the task itself in patients is not likely to explain their final purchase decision because there was no correlation between the missing rate and rate of “yes” answers. Given that the integrating process requires higher-order cognitive functions, such as executive functions, any difficulty in integrating influencing factors may have resulted in this aberrant decision-making pattern in patients. Impairment of executive functions in patients with schizophrenia and the effects of this impairment on decision-making have been well elucidated in various previous studies (Orellana and Slachevsky, 2013). For example, patients with poor executive function have been shown to be more likely to make risky decisions in Iowa gambling task (Wing et al., 2013) and to focus on minor decisions in evidence-integration task (Eifler et al., 2014).

In the purchase phase, fixation time patterns were different from patterns shown in the preceding fit and price phases, suggesting that the purchase phase may involve discrete processes. To make final decisions in the purchase phase, participants should integrate information about preference, fit, and price, which has been gathered in the preceding phases, and re-evaluate the factors if necessary. This is supported by our behavioral findings that the odds ratios of preference, fit, and price for purchase decision were all significant in both groups. According to previous research on perceptual decision-making, a “change of mind” can be explained by accumulation of additional evidence from the sensorimotor system (Gallivan et al., 2018). Patients with schizophrenia have reduced ability in this process; thus, the patients may have made premature purchase decisions due to poor visual exploration.

Although only three factors were considered in our study due to limited experimental conditions, several other factors stand to impact apparel purchase decisions in the normal population. These other influencing factors have been thoroughly investigated in areas of marketing and fashion (Eckman et al., 1990; Sydney et al., 2000; Maria et al., 2011), and may have some influence on aberrant decisions in patients. For example, patients with schizophrenia might be pre-occupied to functionality of clothing to cover and protect their body due to their difficulty in abstract thinking and buy clothes if only the clothing meets that one concrete condition. In addition, patients with schizophrenia might not consider seasonal appropriateness, matching of new clothing with clothing that is already owned, and management of newly purchased clothing as much as the normal population usually do.

F/C fixation time ratios in the purchase phase did not differ between to-buy and not-to-buy decisions in patients, while controls fixed their gaze for relatively shorter durations on clothing that they decided not to buy than on clothing they decided to buy. It has been reported that customers have a greater tendency to purchase items to which they are more exposed and that draw their attention (Peschel and Orquin, 2013;

Gidlof et al., 2017). In real scenarios, attention (as approximated by gaze) increases not only purchase intention, but also purchase rate (Atalay et al., 2012; Velazquez and Pasch, 2014). Because patients with schizophrenia have impairment in their ability to shift eye gaze pattern in flexible ways, they might pay more selective attention to object that they would never actually buy. This impairment in flexible allocation of eye fixation may reflect patients' confusion about their own purchase intentions prior to the purchase phase, thereby leading to their tendency to purchase more clothing as a behavioral response.

However, there was no correlation between F/C fixation time ratio and any clinical and behavioral data gathered in this study. We hypothesized that impaired eye fixation would have a correlation with severity of anhedonia, but the findings were not consistent with this expectation. Instead, impaired eye fixation may be related to deficits in executive functions or abstract thinking, as suggested by the behavior responses of patients in the purchase phase. In previous eye tracking-based research on patients with schizophrenia, an association between greater impairment in identification and lesser fixation count was found only during theme identification and not during sex identification, suggesting the close relationship between abnormal abstract thinking and impaired eye fixation (Oh et al., 2014). In a study on cognitive flexibility, which is an aspect of executive function, healthy adults showed different eye fixation patterns according to version of the Advanced Dimensional Change Card Sort (Chevalier et al., 2010). Taken together, these findings suggest that there may be mediating factors such as abstract thinking and cognitive flexibility between visual exploration and decision-making.

There are several limitations in this study. First, as mentioned, various factors that potentially impact apparel purchase decisions were not fully considered in our behavioral task. Several factors such as clothing brand, seasonality, congruence with clothing already owned, storage of newly purchased clothing, and other factors may have been useful to include in designing the task. Second, we did not observe decision-making processes at the actual behavioral level, but rather at the intentional level. In recent years, however, internet shopping has become a universal way to purchase goods with a simple click for delivery to a person's front door. Given this environment, our task may well reflect real life purchase decisions in spite of our focus on the intentional level. Third, during the task, 4 s, which was the time given to the response, might have been too short to reflect the time spent in the usual purchase decision. Fourth, while extrapyramidal symptoms possibly influence eye movement, these symptoms were not measured. Nevertheless, this factor appears to be inconsequential insofar as there was no correlation between equivalent doses of antipsychotics and fixation time. Lastly, because of time resolution problem of the eye-tracker, eye gaze for less than 80 ms had to be counted as zero, which caused the mean value of fixation time to be less than 80 ms.

In summary, our study is the first attempt to explore the characteristics of decision-making processes via purchase of apparel in patients with schizophrenia through eye tracking. According to our findings, unlike other influencing factors such as fit and price, preference was less important in the final purchase decisions of patients in comparison to controls. Shorter eye gaze fixation time in patients was found only in the purchase phase for the AOI-face, and in all phases except the purchase phase for the AOI-clothes. In addition, shortened gaze fixation on items of clothing that participants decided not to buy was found in controls, but not in patients. Aberrant decision-making behaviors of patients with schizophrenia may be partly induced by inflexible visual information gathering patterns in which patients tend to apportion the same amount of attention to objects, regardless of their purchase intention. However, ineffective visual information gathering in patients with schizophrenia may have been associated with deficits in executive function and abstract thinking rather than with anhedonia. Based on these results, our task can be used as a useful material in the construction of programs to improve social cognition in daily life during social skills training or cognitive remediation programs. Going forward,

research on set-shifting aspects of eye gaze and other influencing factors on purchase behaviors will expand our understanding of decision-making processes in schizophrenia.

Conflicts of interest

None.

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References

- Atalay, A.S., Bodur, H.O., Rasolofoaarison, D., 2012. Shining in the center: central gaze cascade effect on product choice. *J. Consum. Res.* 39, 848–866.
- Barch, D.M., Treadway, M.T., Schoen, N., 2014. Effort, anhedonia, and function in schizophrenia: reduced effort allocation predicts amotivation and functional impairment. *J. Abnorm. Psychol.* 123, 387–397.
- Beedie, S.A., Benson, P.J., St Clair, D.M., 2011. Atypical scanpaths in schizophrenia: evidence of a trait- or state-dependent phenomenon? *J. Psychiatry Neurosci.* 36, 150–164.
- Bestelmeyer, P.E., Tatler, B.W., Phillips, L.H., Fraser, G., Benson, P.J., St Clair, D., 2006. Global visual scanning abnormalities in schizophrenia and bipolar disorder. *Schizophr. Res.* 87, 212–222.
- Bristow, E., Tabraham, P., Smedley, N., Ward, T., Peters, E., 2014. Jumping to perceptions and to conclusions: specificity to hallucinations and delusions. *Schizophr. Res.* 154, 68–72.
- Caldani, S., Amado, I., Bendjema, N., Vialatte, F., Mam-Lam-Fook, C., Gaillard, R., et al., 2017. Oculomotricity and neurological soft signs: can we refine the endophenotype? A study in subjects belonging to the spectrum of schizophrenia. *Psychiatry Res* 256, 490–497.
- Chapman, L.J., Chapman, J.P., Raulin, M.L., 1976. Scales for physical and social anhedonia. *J. Abnorm. Psychol.* 85, 374–382.
- Chevalier, N., Blaye, A., Dufau, S., Lucenet, J., 2010. What visual information do children and adults consider while switching between tasks? Eye-tracking investigation of cognitive flexibility development. *Dev. Psychol.* 46, 955–972.
- Choi, S.H., Ku, J., Han, K., Kim, E., Kim, S.I., Park, J., et al., 2010. Deficits in eye gaze during negative social interactions in patients with schizophrenia. *J. Nerv. Ment. Dis.* 198, 829–835.
- Csukly, G., Polgar, P., Tombor, L., Rethelyi, J., Keri, S., 2011. Are patients with schizophrenia rational maximizers? Evidence from an ultimatum game study. *Psychiatry Res.* 187, 11–17.
- de la Asuncion, J., Dox, L., Sabbe, B., Morrens, M., de Bruijn, E.R., 2015. Abnormal emotion processing, but intact fairness and intentionality considerations during social decision-making in schizophrenia. *Front. Psychol.* 6, 1058.
- Delerue, C., Boucart, M., 2012. The relationship between visual object exploration and action processing in schizophrenia. *Cogn. Neuropsychiatry* 17, 334–350.
- Eckman, M., Damhorst, M.L., Kadolph, S.J., 1990. Toward a model of the in-store purchase decision process: consumer use of criteria for evaluating women's apparel. *Cloth. Text. Res. J.* 8, 13–22.
- Eifer, S., Rausch, F., Schirmbeck, F., Veckenstedt, R., Englisch, S., Meyer-Lindenberg, A., et al., 2014. Neurocognitive capabilities modulate the integration of evidence in schizophrenia. *Psychiatry Res* 219, 72–78.
- Gallivan, J.P., Chapman, C.S., Wolpert, D.M., Flanagan, J.R., 2018. Decision-making in sensorimotor control. *Nat. Rev. Neurosci.* 19, 519–534.
- Gardner, D.M., Murphy, A.L., O'Donnell, H., Centorrino, F., Baldessarini, R.J., 2010. International consensus study of antipsychotic dosing. *Am. J. Psychiatry* 167, 686–693.
- Gidlof, K., Anikin, A., Lingonblad, M., Wallin, A., 2017. Looking is buying. How visual attention and choice are affected by consumer preferences and properties of the supermarket shelf. *Appetite* 116, 29–38.
- Gold, J.M., Strauss, G.P., Waltz, J.A., Robinson, B.M., Brown, J.K., Frank, M.J., 2013. Negative symptoms of schizophrenia are associated with abnormal effort-cost computations. *Biol. Psychiatry* 74, 130–136.
- Hartmann, M.N., Hager, O.M., Reimann, A.V., Chumbley, J.R., Kirschner, M., Seifritz, E., et al., 2015. Apathy but not diminished expression in schizophrenia is associated with discounting of monetary rewards by physical effort. *Schizophr. Bull.* 41, 503–512.
- Heekeren, H.R., Marrett, S., Ungerleider, L.G., 2008. The neural systems that mediate human perceptual decision making. *Nat. Rev. Neurosci.* 9, 467–479.
- Huang, J., Yang, X.H., Lan, Y., Zhu, C.Y., Liu, X.Q., Wang, Y.F., et al., 2016. Neural substrates of the impaired effort expenditure decision making in schizophrenia. *Neuropsychology* 30, 685–696.
- Jang, S.K., Kim, S., Kim, C.Y., Lee, H.S., Choi, K.H., 2016. Attentional processing of emotional faces in schizophrenia: evidence from eye tracking. *J. Abnorm. Psychol.* 125, 894–906.
- Kay, S.R., Fiszbein, A., Opler, L.A., 1987. The positive and negative syndrome scale (PANSS) for schizophrenia. *Schizophr. Bull.* 13, 261–276.
- Kojima, T., Matsushima, E., Ohta, K., Toru, M., Han, Y.H., Shen, Y.C., et al., 2001.

- Stability of exploratory eye movements as a marker of schizophrenia—a WHO multi-center study. World Health Organization. *Schizophr. Res.* 52, 203–213.
- Kwak, Y., Payne, J.W., Cohen, A.L., Huettel, S.A., 2015. The rational adolescent: strategic information processing during decision making revealed by eye tracking. *Cogn. Dev.* 36, 20–30.
- Leckie, S., Gallagher, A., 2011. *Economic, Social, and Cultural Rights: A Legal Resource Guide*. University of Pennsylvania Press, Philadelphia.
- Lee, J.S., Jung, S., Park, I.H., Kim, J.J., 2015. Neural basis of anhedonia and amotivation in patients with schizophrenia: the role of reward system. *Curr. Neuropharmacol.* 13, 750–759.
- Lencer, R., Sprenger, A., Reilly, J.L., McDowell, J.E., Rubin, L.H., Badner, J.A., et al., 2015. Pursuit eye movements as an intermediate phenotype across psychotic disorders: evidence from the B-SNIP study. *Schizophr. Res.* 169, 326–333.
- Maria, H., Anne, H., Pia, P., 2011. An exploration of how mature women buy clothing: empirical insights and a model. *J. Fashion Mark. Manag.* 15, 108–122.
- Matsuzawa, D., Shirayama, Y., Niitsu, T., Hashimoto, K., Iyo, M., 2015. Deficits in emotion based decision-making in schizophrenia; a new insight based on the Iowa Gambling Task. *Prog. Neuropsychopharmacol. Biol. Psychiatry* 57, 52–59.
- Mele, M.L., Federici, S., 2012. Gaze and eye-tracking solutions for psychological research. *Cogn. Process.* 13 (Suppl 1), S261–S265.
- Meyers, J.E., Meyers, K.R., 1995. *Rey Complex Figure Test and Recognition Trial: Professional Manual*. Psychological Assessment Resources, Odessa.
- Morii, M., Ideno, T., Takemura, K., Okada, M., 2017. Qualitatively coherent representation makes decision-making easier with binary-colored multi-attribute tables: an eye-tracking study. *Front. Psychol.* 8, 1388.
- Nikolaides, A., Miess, S., Auvera, I., Muller, R., Klosterkotter, J., Ruhrmann, S., 2016. Restricted attention to social cues in schizophrenia patients. *Eur. Arch. Psychiatry Clin. Neurosci.* 266, 649–661.
- O'Malley, S., Besner, D., 2014. Is eye gaze direction always determined without intent? *Psychon. Bull. Rev.* 21, 1495–1500.
- Oh, J., Chun, J.W., Lee, J.S., Kim, J.J., 2014. Relationship between abstract thinking and eye gaze pattern in patients with schizophrenia. *Behav. Brain. Funct.* 10, 13.
- Orellana, G., Slachevsky, A., 2013. Executive functioning in schizophrenia. *Front. Psychiatry* 4, 35.
- Peschel, A.O., Orquin, J.L., 2013. A review of the findings and theories on surface size effects on visual attention. *Front. Psychol.* 4, 902.
- Radua, J., Schmidt, A., Borgwardt, S., Heinz, A., Schlagenhauf, F., McGuire, P., et al., 2015. Ventral striatal activation during reward processing in psychosis: a neuro-functional meta-analysis. *JAMA Psychiatry* 72, 1243–1251.
- Raven, J., 2000. The Raven's progressive matrices: change and stability over culture and time. *Cogn. Psychol.* 41, 1–48.
- Rayner, K., 2009. Eye movements and attention in reading, scene perception, and visual search. *Q. J. Exp. Psychol.* 62, 1457–1506.
- Shadlen, M.N., Kiani, R., 2013. Decision making as a window on cognition. *Neuron* 80, 791–806.
- Spitzer, R., Williams, J., Gibbon, M., First, M., 1994. *Structured Clinical Interview for DSM-IV*. Biometrics Research, New York.
- Sproles, G.B., Kendall, E.L., 1986. A methodology for profiling consumers' decision-making styles. *J. Consum. Aff.* 20, 267–279.
- Starke, S.D., Baber, C., 2018. The effect of four user interface concepts on visual scan pattern similarity and information foraging in a complex decision making task. *Appl. Ergon.* 70, 6–17.
- Strauss, G.P., Visser, K.F., Keller, W.R., Gold, J.M., Buchanan, R.W., 2018. Anhedonia reflects impairment in making relative value judgments between positive and neutral stimuli in schizophrenia. *Schizophr. Res.* 197, 156–161.
- Sydney, R., Tiger, L., Nicholls, J.A.F., 2000. Impact of situational variables and demographic attributes in two seasons on purchase behaviour. *Eur. J. Mark.* 34, 1167–1180.
- Thibaut, F., Boutros, N.N., Jarema, M., Oranje, B., Hasan, A., Daskalakis, Z.J., et al., 2015. Consensus paper of the WFSBP Task Force on Biological Markers: criteria for biomarkers and endophenotypes of schizophrenia part I: neurophysiology. *World J. Biol. Psychiatry* 16, 280–290.
- Toh, W.L., Rossell, S.L., Castle, D.J., 2011. Current visual scanpath research: a review of investigations into the psychotic, anxiety, and mood disorders. *Compr. Psychiatry* 52, 567–579.
- Treadway, M.T., Peterman, J.S., Zald, D.H., Park, S., 2015. Impaired effort allocation in patients with schizophrenia. *Schizophr. Res.* 161, 382–385.
- Velazquez, C.E., Pasch, K.E., 2014. Attention to food and beverage advertisements as measured by eye-tracking technology and the food preferences and choices of youth. *J. Acad. Nutr. Diet.* 114, 578–582.
- Wang, J., Huang, J., Yang, X.H., Lui, S.S., Cheung, E.F., Chan, R.C., 2015. Anhedonia in schizophrenia: deficits in both motivation and hedonic capacity. *Schizophr. Res.* 168, 465–474.
- Wesley, S., LeHew, M., Woodside, A.G., 2006. Consumer decision-making styles and mall shopping behavior: building theory using exploratory data analysis and the comparative method. *J. Bus. Res.* 59, 535–548.
- Wing, V.C., Rabin, R.A., Wass, C.E., George, T.P., 2013. Correlations between executive function, decision-making and impulsivity are disrupted in schizophrenia versus controls. *Psychiatry Res.* 205, 168–171.
- Wischniewski, J., Brune, M., 2011. Moral reasoning in schizophrenia: an explorative study into economic decision making. *Cogn. Neuropsychiatry* 16, 348–363.
- Wolf, D.H., Satterthwaite, T.D., Kantrowitz, J.J., Katchmar, N., Vandekar, L., Elliott, M.A., et al., 2014. Amotivation in schizophrenia: integrated assessment with behavioral, clinical, and imaging measures. *Schizophr. Bull.* 40, 1328–1337.
- Zommaro, N.M., Takahashi, M., Ounjai, K., Lauwereyns, J., 2018. A gaze bias with coarse spatial indexing during a gambling task. *Cogn. Neurodyn.* 12, 171–181.