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Lay Abstract

Many autistic people report difficulties making decisions during everyday tasks, such as shopping. To examine the effect of sounds on decision-making, we developed a supermarket task where people watched a film shown from the shopper's perspective and were asked to make decisions between different products. The task was divided into three sections and participants completed each section in a different auditory environment: a) no sounds, b) non-social sounds (e.g. fridges humming) and c) social sounds (e.g. people talking). Thirty-eight autistic and 37 neurotypical adults took part. We measured decision-making by examining how long it took to make a decision and how consistent people were with their decisions. We also measured heart rate variability because this biological response provides a measure of anxiety. After the supermarket shopping task, participants told us in their words about their experiences. Autistic participants said that they found the non-social and social sound conditions more difficult than the no sound condition, and autistic participants found the social sound condition more negative than neurotypical participants. However, decision-making and heart rate variability were similar for autistic and neurotypical participants across the sound conditions, suggesting that these measures may not have been sensitive enough to reflect the experiences the autistic participants reported. Further research should consider alternative measures to explore the experiences reported by autistic people to help us understand which specific aspects of the environment autistic people are sensitive to. This, in turn, may enable more specific and evidence-based autism-friendly changes to be made.

Abstract

Autistic people report difficulties with the demands of a neurotypical world, but little research has assessed the impact of the environment on such difficulties. We investigated the effect of ambient sounds on decision-making and heart rate variability. Adults without intellectual disability were allocated to autistic (n=38) or neurotypical (n=37) groups matched on age, intellectual functioning and self-reported gender. Participants completed a shopping decision-making task in three randomly ordered sound conditions: no sound, non-social shopping sound (e.g. fridges humming) and social shopping sound (e.g. people talking). Decision-making latency, decision-making consistency and heart rate variability were measured. Participants also provided qualitative reports of their experiences. Qualitative analyses indicated that autistic participants experienced a) the non-social and social sound conditions more negatively than the no sound condition and b) the social sound condition more negatively than NT participants. However, there were no statistically significant differences in decision-making latency, decision-making consistency or heart rate variability across sound conditions and participant groups. Further research should consider alternative quantitative measures to explore subjective experience to help understand further which aspects of the environment autistic people are sensitive to, in turn, enabling more evidence-based autism-friendly changes to be made.

Introduction

Difficulties in Shopping Environments

The 'neurotypical (NT) world' is challenging for autistic[1] people (Crane, Adams, Harper, Welch & Pellicano, 2019; Krieger et al., 2018) and shops are particularly difficult: about two-thirds of autistic individuals (n=not provided) across the UK report they avoid shopping (National Autistic Society [NAS], 2018). There are likely to be many reasons, including those reflecting the social difficulties of autism (American Psychiatric Association, 2013).

Shopping-related challenges may be exacerbated by the sensory sensitivities, including sound sensitivity (Lucker, 2013; Stiegler & Davis, 2010), and anxiety often experienced by autistic people. Self-reports suggest unpredictable and uncontrollable sounds, competing sounds from multiple inputs and sounds that are loud, distracting or are very high or low frequency (Smith & Sharp, 2013) are particularly aversive. Autism is also associated with high rates of comorbid anxiety (Croen et al., 2015; Hollocks et al., 2019; Lai et al., 2019; Lugo-Marín et al., 2019), and a greater proportion of autistic than NT adults are prescribed anxiolytics (Vella et al., 2018). Self-reports and longitudinal analyses indicate sensory stimuli, specifically sound stimuli, can lead to anxiety in autism (Green, Ben-Sasson, Soto, & Carter, 2012; Landon, Shepherd & Lodhia, 2016).

Outcomes in Everyday Life: Decision-Making

Autistic individuals report that everyday decisions are problematic (Lawson, 2001; Sainsbury, 2000). Luke, Clare, Ring, Redley & Watson (2012) investigated the self-reported decision-making difficulties of 38 autistic individuals without intellectual disability compared

[1] Kenny et al. (2016) found a large percentage of autistic people and their families and friends endorsed the term 'autistic'.

to 40 NT individuals. Autistic individuals reported more frequent decision-making difficulties and greater avoidance of decision-making than NT individuals. Three kinds of decisions appeared particularly challenging: those that had to be made quickly, involved a change of routine and/or required talking to other people. Gaeth, Levin, Jain, & Burke (2016) found autistic adults rated everyday decisions as more difficult than NT adults.

Autism-Friendly Initiatives

The findings of focus groups involving 1,213 autistic people, their families, and clinicians have emphasised the importance of research-based evidence to promote environments that improve experiences for autistic people (Cusack & Sterry, 2016). The NAS organises a week each year during which businesses are supported in making their services more autism-friendly, such as by turning off music and dimming lights (NAS, 2019). However, there seems to be no experimental evidence to support these initiatives.

The Present Study

We used an experimental paradigm that modelled supermarket shopping to investigate how the auditory environment may impact two areas of difficulty in autism: decision-making and anxiety. Decision-making was measured using the attraction effect (AE) paradigm (Huber, Payne & Puto, 1982). The paradigm elicits a context effect, where the addition of an alternative option in a choice influences decision-making (Mourali et al., 2007) and contrasts with 'rational' decision-making (Luce, 1959, 1977; Tversky, 1972) (Supplementary Material 1). Two aspects of decision-making are measured: *latency* and *consistency.* Farmer, Baron-Cohen & Skylark (2017) found autistic adults had longer response latencies than NT adults when making AE choices. However, compared with NT adults, autistic people made significantly more consistent choices, suggesting they demonstrated more rational decision-making.

Interactions between anxiety and decision-making are well-known in the literature (eg. Remmers & Zander, 2018; Santos-Ruiz et al., 2012), and so is the high prevalence of anxiety in autism (Croen et al., 2015; Hollocks et al., 2019; Lai et al., 2019; Lugo-Marín et al., 2019). To better understand the role of anxiety in our shopping paradigm, heart rate variability (HRV) was measured to index general adaptive capacity to anxiety (Klusek, Roberts & Losh, 2015; Mertens, Zane, Neumeyer & Grossman, 2017). While HRV reduction in response to a stressor typically reflects an adaptive response, resting-state reductions reflect chronic arousal and autonomic inflexibility (Quintana, Alvares & Heathers, 2016). Autism has been associated with autonomic atypicalities (Benevides & Lane, 2015; Klusek et al., 2015), but the literature is contradictory. Some studies that compare HRV in autistic adults and NT adults report no differences in resting HRV (Dijkhuis, Ziermans, van Rijn, Staal & Swaab, 2019; Smeekens, Didden & Verhoeven, 2015) or HRV in response to a stimulus (Kuiper, Verhoeven & Geurts, 2017; Smeekens et al., 2015). However, others report reduced resting HRV in autistic adults (Cai, Richdale, Dissanayake & Uljarević, 2019; Kuiper et al., 2017; Mathewson et al., 2011; Thapa et al., 2019) and reduced HRV reactivity in response to a stimulus (Dijkhuis et al., 2019), compared to NT adults. Some studies have assessed the effects of auditory stimuli on HRV in autistic individuals. For example, respiratory sinus arrhythmia (RSA), an index of HRV, was measured in autistic and NT children aged 6-9 years while they listened to different auditory tones (Schaaf, Benevides, Leiby & Sendecki, 2015); no differences in RSA were found. In contrast, Porges et al. (2013), found RSA to increase in autistic individuals (aged 6 to 21) during an auditory processing task. The effects of ambient environmental conditions on HRV in autistic adults are yet to be investigated.

We expected there would be differences between autistic and NT groups in the effect of different kinds of sounds on (i) decision-making latency; (ii) decision-making consistency; and (iii) HRV. Based on the greater sensory sensitivity of autistic individuals compared with

NT adults (Crane et al., 2019), and the everyday decision-making difficulties (Gaeth et al., 2016; Luke et al., 2012) and anxiety in response to sensory stimulation (Landon et al., 2016) of autistic people, we also expected an interaction between these variables and the group (autistic/NT) to which participants belonged.

Methods

Ethics

The study was reviewed by XXXX (identifiable information removed).

Participants

Participants were at least 18 years old, were native English speakers, had not taken part in an AE pilot (Supplementary Material 2) and possessed corrected-to-normal vision and hearing. Participants had tested IQ scores ≥90 (Wechsler Abbreviated Scale of Intelligence, 2nd Edition [WASI-II]; Wechsler, 2011), with 20% of the assessments scored by two independent raters. Full Scale IQ was used to indicate IQ except for six autistic and six NT participants where Verbal Comprehension Index (VCI) was used because VCI and Perceptual Reasoning Index differed significantly.

Autistic participants (i) self-reported an autism diagnosis and (ii) scored above the cut-off for autism spectrum disorder on the Autism Diagnostic Observation Schedule-Second Edition (ADOS-2; Hus & Lord, 2014), Module 4. NT participants (i) self-reported they did not have an autism diagnosis and (ii) scored below 32 on the Autism-Spectrum Quotient (AQ; Baron-Cohen et al., 2001).

Power was estimated using Farmer et al. (2017). To detect a clinically meaningful difference of 10 seconds in decision-making latency between autistic and NT groups whilst listening to social sounds, 30 participants were needed in each group (α=0.05) allowing detection of a Cohen's *d* of 0.88 (two-tailed) with 90% power (Altman, 1991).

Advertisements were distributed through the Cambridge Autism Research Centre, National Autistic Society, local student and community contacts, and autism support services.

All participants provided informed written consent for participation.

Materials

Shopping Decision-Making Task

The shopping task was based on that of Braeutigam, Stins, Rose, Swithenby & Ambler (2001; also see Ambler, Braeutigam, Stins, Rose & Swithenby, 2004). It comprised a film from a shopper's perspective (Supplementary Material 3) and AE choices. The task was completed in no sound, non-social sound and social sound conditions.

The video and sound clips were recorded in a supermarket and further sounds were retrieved from sound banks. Piloting was completed to identify the choices and sounds to use (Supplementary Material 2). The task was programmed with Python.

The shopping task contained 54 AE choices across nine products (six choices per product). The task was split into three sections, each occurring in a different sound condition and comprising 18 choices, across three products. The order the products appeared was randomised. Each of the sound conditions began with the participant watching a video of a shopper entering a supermarket and approaching a product. The participant then made three pairs of choices about that product, before watching the shopper approach a second product and making three further pairs of choices. The participant then watched a video and made three pairs of choices about a third product, before seeing the shopper leave the supermarket. This process occurred three times, once in each sound condition.

Each choice was presented on a separate page and referred to one product (Supplementary Material 4). A picture of the product was given and remained the same for all six choices for that product. For each choice, there were three options: a target, competitor and decoy. Each option was described in terms of two attributes (Supplementary Material 4). The three options were presented in a triangle and the location of the options was randomised (Paulhus & Vazire, 2007). Participants could not change their choice once made.

Choices were grouped into pairs. Each pair of choices involved the same attributes, attribute descriptors and non-decoy options, but the decoy targeted a different option in each choice. The order of the choices was randomised, but all the first choices in a pair were shown before any of the second choices in a pair.

Ten-minute sound collages were produced using Audacity 2.3.0 (Audacity Team, 2018). All sound clips occurred in the first six minutes of the collage to ensure participants who completed the shopping task quickly were still exposed to most sounds. In the last four minutes, sounds were repeated.

Demographic Interview

Participants provided information on their demographics, diagnoses (including reading, listening and sensory impairments), and current medication.

Familiarity, Knowledge and Preference Questionnaire

Familiarity (Mishra, Umesh & Stem, 1993; Ratneshwar, Shocker & Stewart, 1987), knowledge (Malaviya & Sivakumar, 1998; Mishra et al., 1993) and preference of shopping products (Malkoc, Hedgcock & Hoeffler, 2013) may be important to AE decision-making, so were measured.

Participants indicated their familiarity and knowledge with each product on a four-point scale (scored 0-3) and their preference for each product on a five-point scale (scored 0-4). Participants received three scores by calculating the median values for familiarity, knowledge and preference across products. Higher scores indicated greater familiarity, knowledge or preference.

Subjective reports

Participants remained in the same room after the three sound conditions, so the first author could ask them 'how did you find the experience?'. Participants were asked about each sound condition in the order it had been presented. The participants' responses were transcribed verbatim.

Heart Rate Variability

Equipment and Protocol. A Zensor v0 Intelesens Ltd monitor recorded electrocardiogram (ECG) and respiration data using 3-lead monitoring, sampling at 360Hz (Laborde et al., 2017). Participants remained seated and upright, given the relationship between posture and HRV (Montano et al., 1994; Mukai & Hayano, 1995). Time of day of the recordings (morning, early afternoon, late afternoon or evening) did not differ between participant groups [Fisher's exact test value=5.32, p=0.12].

HRV Questionnaire. To inform the HRV analysis, self-reported information about recent eating, sleeping and caffeine consumption was recorded, together with use of oral contraceptives, and urgency of need to use a bathroom.

Procedure

Participants attended one session lasting approximately 2.5 h. Sessions took place in one of two similar rooms. Participants completed the AQ and Product Familiarity, Knowledge and Preference Questionnaire before the session.

The order of the procedure ensured more and less demanding tasks were alternated, reducing fatigue (Lezak, Howieson, Loring, Hannay & Fischer, 2004). To begin, participants answered demographic questions and completed a hearing assessment: the sound of a phone ringtone was played and participants had to describe the sound to pass.

Participants then completed the WASI-II, followed by time-dependent questions in the HRV questionnaire. Subsequently, the HRV equipment was set-up. Participants were given an instruction sheet and the researcher left the room while the participant set-up the equipment, to ensure privacy.

Baseline heart rate measurement then took place, lasting 10 minutes. For approximately the first four minutes, the participant was given verbal and written instructions for the shopping task. Consistent language was used across participants when explaining how to complete the AE choices; 'click on the one [option] you would prefer if you had to choose between them' (Farmer et al., 2017). For the remaining time participants watched a nature film.

The shopping task was completed on the same computer by all participants with screen brightness, contrast and resolution all constant. Windows were covered to remove natural light variation and the lights were turned off. The researcher remained in the room, out of sight. The order of the sound conditions was randomised and the sound collages were played through speakers at approximately 78 decibels. Sound collages were looped if necessary. Between each condition, participants watched five minutes of the nature film. The researcher requested that the participant stayed seated. After the task was complete, participants were prompted to discuss each sound condition. Participants then finished the HRV questionnaire. The ADOS-2 was completed at the end of the session to ensure task order between NT and autistic groups remained as similar as possible.

All participants were paid, sent a letter of thanks, and those who had agreed to their contact details being retained were sent a layperson's summary of the findings.

Analysis

Heart Rate Variability Pre-Processing

ECG processing was completed with Kubios 3.2.0, which uses an in-built QRS detection algorithm, based on the Pan-Tompkins algorithm (Pan & Tompkins, 1985). After peak detection, cubic spline interpolation of the RR time series occurred at four hertz and a smoothness prior detrending method (smoothing parameter, lambda=500) reduced the influence of very low-frequency components. The ECG trace was inspected manually to ensure correct QRS recognition. Participant information known to influence ectopic beats was considered during inspection. Ectopic beats and subsequent heart rate turbulence were corrected by altering R peak marks. Subsequent threshold-based artefact correction was applied on a participant-level basis if the RR interval trace showed outliers. The level of artefact correction was determined by applying the lowest threshold level which removed all spurious results. There was no difference in the percentage of heart beats corrected between autistic and NT groups [mean difference=-0.13, 95% CIs -1.11-0.83, U=313, p=0.72, d=-0.10].

For each participant, four 2.5 min samples were assessed (Esco & Flatt, 2014; Laborde et al., 2017; Munoz et al., 2015). The baseline sample was taken from the final 2.5 min of the baseline period to allow acclimatisation to the equipment (Quintana et al., 2016). For the sound conditions, samples were taken from the first 2.5 min of each condition. The high-frequency (HF) band was defined as 0.15-0.4Hz, as recommended for adults (Quintana et al., 2016). When, for the baseline recording, there was five percent artefact correction or more (Quintana & Heathers, 2014) or the electrocardiogram derived respiration (EDR) was outside the HF band, the sample was moved as close to the end of the baseline period as possible while allowing for artefact correction below five percent and HF band EDR placement. For the sound conditions, the sample was moved as close to the beginning of each condition as possible, while allowing for less than five percent artefact correction and HF band EDR placement. If a sample with less than five percent artefact correction and HF band EDR placement was not found in the last five minutes of the baseline period or within the sound conditions, the participant was excluded.

The root mean square of successive differences (RMSSD), high-frequency heart rate variability (HF-HRV) and heart rate were exported from Kubios to SPSS and RStudio. HF-HRV was calculated through autoregressive modelling (AR), since AR produces a spectrum with greater resolution than other methods when short samples are used (Laborde et al., 2017). AR was measured through absolute power, as advised by Laborde et al. (2017). Model order was 16 (Boardman, Schlindwein, Rocha & Leite, 2002; Dantas et al., 2012).

Baseline respiration was measured by manually counting the number of respiratory cycles in the respiratory waveform displayed by the Zensor+ software during baseline.

Statistical Analyses

Psychotropic medication and comorbid psychiatric conditions influence decision-making (Brand, Labudda & Markowitsch, 2006; Hauser, Moutoussis, Purg, Dayan & Dolan, 2018) so were considered as confounds in the decision-making latency and consistency analyses. For psychotropic medication, participants were given a score of 1 if they were currently taking any psychotropic medication and a score of 0 if they were not. For comorbid psychiatric conditions, participants were given a score of 1 if they currently had any psychiatric conditions; and again, a score of 0 if they did not. These categorical variables were included in a stepwise regression to assess their impact on decision-making latency and consistency. Product preference, knowledge and familiarity scores were also included in the stepwise regression for decision-making consistency, given the research to suggest these factors influence AE choosing behaviour (Malkoc et al., 2013; Mishra et al., 1993).

Given the impact of comorbid conditions, psychotropic medication and medication known to impact heart rate on HRV in NT (Laborde et al., 2017) and adult autistic groups (e.g.

Thapa et al., 2019), these variables are often controlled for in HRV studies. We therefore assessed the impact of these variables on HRV through a stepwise regression. For psychotropic medication, participants were given a score of 1 if they were currently taking any psychotropic medication and a score of 0 if they were not. For medication known to impact heart rate, participants were given a score of 1 if they were currently taking any medication known to impact heart rate and a score of 0 if they were not. For comorbidites impacting HRV, participants were given a score of 1 if they currently had any comorbidites known to impact HRV and a score of 0 if they did not.

Variables which contributed to stepwise regression models at $p \leq 0.05$ were added as confounds to the ANOVAs testing the hypotheses.

Assumptions underlying the use of parametric tests comparing the autistic and NT groups were checked and, where required, transformations were made to the data or non-parametric tests were used. For variables where the data were transformed, the reported values reflect this, apart from means, standard deviations, mean differences and 95% CIs where raw values are reported. Tests were two-tailed and run at α=0.05.

Community Involvement

This research was developed to target one of the areas which the autism community (autistic people, their families and clinicians) highlight as needing more attention: research to better understand how environments can improve experiences for autistic people (Cusack & Sterry, 2016). In addition, one autistic individual provided feedback that was used to inform the wording of recruitment advertisements and payment for participants.

Results

Raw data and research materials are available on request to the corresponding author.

Participants

Forty-five autistic and 37 NT individuals participated. Of these, seven autistic participants were excluded: three with a tested IQ score below 90, three below the ADOS-2 cut-off, and one due to technical issues. Thirty-eight autistic and 37 NT participants were included in the analyses. More than three-quarters (79%) described themselves as White British (Supplementary Material 5). Twenty-two autistic participants self-reported a diagnosis of anxiety and 20 a diagnosis of depression, compared to four NT participants who self-reported anxiety and four who self-reported depression (Supplementary Material 6). Thirty autistic and 17 NT individuals self-reported taking medication, with 25 autistic participants reporting using psychotropic medication, compared to five NT participants (Supplementary Material 7).

Sixteen autistic participants and 13 NT participants were employed. Twenty-two autistic participants and 24 NT participants were unemployed. Twenty-four autistic and 33 NT participants had at least one degree or were currently completing a degree.

Table 1 shows the characteristics of the participants included in the analyses. Fisher's exact test was used in the analysis of product familiarity, preference and knowledge because more than 20% of expected values fell below five. Product familiarity [Fisher's exact test value=6.27, p=0.06] and knowledge [Fisher's exact test value=1.39, p=0.61] did not differ between autistic and NT groups, but autistic participants gave significantly higher product preference scores than NT participants [Fisher's exact test value=10.71, p=0.01] (Supplementary Material 8).

Table 1

Age, Intellectual Functioning (IQ), Autism Quotient (AQ) Scores and Self-Reported Gender across Participant Groups

Variable	Autistic Mean	Autistic SD	NT Mean	NT SD	95% CIs	*df*	*t*-value	*p*-value	Cohen's *d*
Age (years)	38.76	14.19	37.92	18.06	-6.62-8.31	73	0.23	0.82	0.05
IQ	113.7	12.00	112.8	10.54	-4.2-6.2	73	0.38	0.71	0.09
AQ^{T}	37.7	7.42	12.7	6.10	21.8-28.1	73	15.07	<0.001*	3.48
Variable	Autistic Frequencies		NT Frequencies			*df*	χ^2 value	*p*-value	Cramer's *V*
Self-Reported Gender	Man=18, Woman=20		Man=16, Woman=21			1	0.02	0.90	0.041

T=Data were cube-root transformed due to raw data not being normally distributed.

*=$p \leq 0.05$.

Participants' Self-Report

The responses of autistic (n=38) and NT (n=15) participants to the sound conditions (Figure 1) were analysed. A response was categorised as positive when the participant's comments were entirely positive, for example, describing the experience as relaxing or easy. Comments that made no reference to positive or negative experiences, references to both positive and negative experiences or described the use of coping mechanisms were categorised as neutral. A negative categorisation was given when the participant's comments were entirely negative, for example, describing difficulty or fear. Negative experiences were coded as one, neutral as two and positive as three. Responses were independently coded by two of the authors. Prior to a consensus meeting, Cohen's kappa equalled 0.81 [95% CIs 0.71-0.90, p<0.001]. After the meeting, full agreement was met [k=1.00, p<0.001]. Sample comments are shown in Supplementary Material 9.

[INSERT FIGURE 1 HERE]

A Friedman test indicated a significant difference across the sound conditions within the autistic group [$\chi^2(2)=54.12$, $p<0.001$]. Bonferroni-corrected post-hoc tests indicated responses to the no sound condition were significantly more positive than responses to the non-social sound [$p<0.001$, $d=1.37$] and social sound conditions [$p<0.001$, $d=2.06$], but no significant differences were seen between the non-social and social sound conditions [$p=0.56$, $d=0.31$]. To test, whether a group (autistic/NT) by sound condition interaction existed, a log-linear analysis was completed. A significant three-way interaction was found [$\chi^2(4)=8.82$, $p=0.05$], suggesting there was a difference in the qualitative ratings between the autistic and NT groups across the three sound conditions. Bonferroni-corrected post-hoc tests revealed there was no difference between the autistic and NT groups' qualitative ratings in the no sound [Fisher's exact test value=2.03, $p=0.44$] and non-social sound [Fisher's exact test value=2.85, $p=0.22$] conditions, but the autistic group produced significantly more negative ratings than the NT group in the social sound condition [Fisher's exact test value=16.51, $p<0.001$].

Decision-Making Latency

Figure 2 highlights decision-making latency in autistic and NT groups across sound conditions (Supplementary Material 10). The group x sound condition interaction [$F(2, 146)=0.98$, $p=0.38$, $\eta^2_p=0.013$], main effect for sound condition [$F(2, 146)=2.44$, $p=0.09$, $\eta^2_p=0.032$] and main effect for participant group [$F(2, 73)=2.53$, $p=0.12$, $\eta^2_p=0.033$][2] were non-significant.

[INSERT FIGURE 2 HERE]

A stepwise regression was completed with backward elimination of comorbid psychiatric conditions and psychotropic medication as categorical variables. Neither psychiatric comorbidities nor psychotropic medication significantly contributed to the model [$p \geq 0.43$] and so were not added to the ANOVA.

Decision-Making Consistency

[2]For one participant, the latency of one choice in the social sound condition was missing. Average latency for the social sound condition was calculated using the remaining 17 choices.

Figure 3 shows decision-making consistency for autistic and NT groups across sound conditions[3] (Supplementary Material 10). The group x sound condition interaction [$F(2, 146)=2.82$, $p=0.06$, $\eta^2_p=0.037$], main effect for sound condition [$F(2, 146)=0.66$, $p=0.52$, $\eta^2_p=0.009$] and main effect for participant group [$F(1, 73)=0.21$, $p=0.65$, $\eta^2_p=0.003$] were non-significant.

[INSERT FIGURE 3 HERE]

To assess those variables needing to be controlled in the ANOVA, a backward elimination of the following variables was completed: psychotropic medication, comorbid psychiatric conditions, product knowledge, product familiarity and product preference. Psychotropic medication significantly contributed to the final model [$p=0.05$], so the ANOVA was repeated with psychotropic medication as a factor. All effects were non-significant [$F\leq1.95$, $p\geq0.15$, $\eta^2_p\leq0.027$].

[3]For one participant, the option chosen for one choice in the social sound condition was missing. Average decision-making consistency for the social sound condition was calculated using the eight complete choice pairs.

Heart Rate Variability

HRV data were analysed for 30 autistic and 22 NT participants. Groups were matched on age, self-reported gender and IQ (Supplementary Material 11). Eighteen participants were excluded due to a lack of ECG trace; two due to data only being available for a 1.5 min sampling period in one or more sound conditions; one due to artefact correction being over five percent; and one due to ECG-derived respiration being outside the high frequency band. Failures were likely produced as the result of participants setting-up the ECG equipment independently. This procedure could not be altered due to participant privacy.

To establish whether exclusions from the HRV analysis were linked to participant group, a chi-square test was completed to compare HRV recording success (autistic: n=30, NT: n=22) and failure (autistic: n=8, NT: n=15) between groups; the difference was not significant [$\chi^2(1)=2.50$, $p=0.11$, $V=0.21$).

Forty-two individuals were included in the baseline respiration analysis (autistic: n=24, NT: n=18): baseline respiration could not be determined for five individuals because of a noisy respiratory trace and for another five due to a weak signal. HRV confounds were analysed for 24 participants (autistic: n=18, NT: n=6).

There were no differences in baseline heart rate, HRV or respiration between participant groups (Table 2).

Table 2

Baseline Heart Rate, HRV and Respiration across Participant Groups

Variable	Autistic Mean	Autistic SD	NT Mean	NT SD	95% CIs	*df*	*t*-value	*p*-value	Cohen's *d*
Baseline Heart Rate (bpm)	71.19	8.45	69.73	8.40	-3.29–6.22	50	0.62	0.54	0.17
Baseline RMSSD (HRV, ms)^{T}	37.75	23.90	42.52	23.67	-8.64–18.19	50	-0.72	0.48	0.20
Baseline HF-HRV (HRV, ms^{2})^{T}	893.94	1504.28	816.82	900.39	-647.73–801.96	50	0.39	0.70	0.11
Variable	Autistic Mean	Autistic SD	NT Mean	NT SD	95% CIs	*u*-value	*p*-value		*d*
Baseline Respiration (number of breaths during baseline)^{M}	38.33	7.82	40.06	5.89	15.56–-12.12	176	0.31		-0.32

T=Data were transformed due to raw data not being normally distributed. Baseline RMSSD=square-root transformation. Baseline HF-HRV=log-transformation.

M=A Mann-Whitney U test was used since data transformation did not lead to normality.

*=$p \leq 0.05$.

Figure 4 shows RMSSD across participant groups in the sound conditions (Supplementary Material 10). HRV was measured through log-transformed RMSSD values, since raw data violated the assumption of normality of residuals. The group x sound condition interaction [$F(2, 100)=0.75$, $p=0.48$, $\eta^2_p=0.015$], main effect for sound condition [$F(2, 100)=1.42$, $p=0.25$, $\eta^2_p=0.028$] and main effect for participant group [$F(1, 50)=0.08$, $p=0.78$, $\eta^2_p=0.002$] were non-significant. These results were replicated with HF-HRV (Supplementary Material 12).

[INSERT FIGURE 4 HERE]

To understand the influence of medication and comorbidities on RMSSD (log-transformed), a stepwise regression was completed with backward elimination of three categorical variables: comorbidities believed to impact HRV, 'medications that impact heart rate' and psychotropic medications. Both the 'medications that impact heart rate' [$p \leq 0.001$] and psychotropic medication [$p=0.006$] variables had a significant influence on the final model, so were included as factors in the ANOVA; all interactions with RMSSD were non-significant [$F \leq 1.63$, $p \geq 0.20$, $\eta^2_p \leq 0.036$]. The results of these analyses (stepwise regression and ANOVA) were replicated with log-transformed HF-HRV [$F \leq 2.76$, $p \geq 0.069$, $\eta^2_p \leq 0.059$].

Discussion

Qualitative measures suggested the social sound condition was experienced more negatively by the autistic than NT participants. However, the hypotheses were supported: there were no statistically significant decision-making latency, decision-making consistency or HRV differences across sound conditions and participant groups.

The finding that autistic participants experienced the social sound condition more negatively than NT participants is expected given the social difficulties characterising autism (American Psychiatric Association, 2013). The difference in qualitative ratings between the autistic and NT groups in the social sound condition but not the non-social sound condition, suggests difficulties experienced by autistic individuals, as compared to NT individuals, in these ambient environments may be related to the social aspects of sounds, rather than a generalised sensitivity to all sounds. It is also possible the social sounds were characterised by features which autistic individuals self-report as particularly difficult, such as unpredictable, loud, or very high or low frequency sounds (Smith & Sharp, 2013). However, within the autistic group, both ambient sound conditions were rated more negatively than the no sound condition, suggesting benefit to reducing both non-social, such as checkout beeps, and social, such as loud conversations, sounds to make supermarkets more autism-friendly.

The lack of difference in decision-making and HRV measures between the non-social and social sound conditions in the autistic group is unexpected and noteworthy. This result is not in line with theories suggesting autism is due to inherent social difficulties (e.g. Baron-Cohen et al., 1985), which would predict the social sound condition would create more difficulty for autistic people than the non-social condition. Such results could be better explained by attentional theories of autism (e.g. Liss, Saulnier, Fein & Kinsbourne, 2006; Ploog, 2010; Tyndall et al., 2017) which suggest autistic individuals show broader atypicalities in attention, rather than specific social deficits. Prediction deficit models of autism (e.g. Sinha et al., 2014) may also better explain these results by suggesting autistic individuals rely less on prior expectations relative to sensory inputs, leading to broad perceptual atypicalities rather than atypicalities specific to the social domain. The presence of a participant group by sound condition interaction in the qualitative analysis should, however, be noted, since this interaction indicates that there are differences in the impact of social, but not non-social, sounds between autistic and NT individuals.

The absence of differences in decision-making between participant groups was unexpected based on self-reported decision-making difficulties in autism (Gaeth et al., 2016; Luke et al., 2012) and Farmer et al.'s (2017) findings of increased latency and consistency in autistic, compared to NT, adults. In the present study, the autistic participants' reports highlighted the negative experience of the social and non-social sound conditions, suggesting the participants faced difficulties with the shopping task. Measures of latency and consistency may not have been sufficiently sensitive to reflect the subjective experience of autistic participants and participants' difficulties may have gone undetected.

The outcome measures must be considered in terms of whether they reflect everyday decision-making. Taking a long time to make decisions is reported by autistic participants as an everyday difficulty (Luke et al., 2012), supporting the use of latency. However, decision-making consistency may not reflect decision-making in everyday life, since individuals rarely make several choices regarding the same product. There are methods to improve the everyday relevance of the AE paradigm, such as offering a no-buy option, but these are not validated with autistic participants (Hadar, Danziger, & Hertwig, 2018; Lichters, Sarstedt & Vogt, 2015; Stewart, 1989).

Our findings add to the inconsistencies in the HRV literature: some studies have found baseline/task-driven HRV differences between autistic and NT adults, but others have not (Cai et al., 2019; Dijkhuis et al., 2019; Kuiper et al., 2017; Mathewson et al., 2011; Smeekens et al., 2015; Thapa et al., 2019).

The absence of baseline differences in HRV between participant groups was surprising, given that 22 autistic participants self-reported 'anxiety' compared to only 4 NT participants (Supplementary Material 6). However, 'anxiety' is often used informally rather than according to standard diagnostic classifications (such as DSM-V, American Psychiatric Association, 2013; ICD-10, World Health Organization, 1992) to include a range of worries and fears, with different levels of impact. The relationship between these self-reports, which are very common in autistic people (Zaboski & Storch, 2018), and 'anxiety' as measured by HRV is uncertain. While we controlled for medication use and comorbidities known to impact HRV, it is possible that the signal may have been affected by variables that were uncontrolled, such as smoking (Kemp, Koenig & Thayer, 2017; Murgia et al., 2019), body mass index (Föhr et al., 2016; Koenig et al., 2014), physical activity (Kemp et al., 2017; May, McBerty, Zaky & Gianotti, 2017), and alcohol (Ralevski, Petrakis & Altemus, 2019) and water (Heathers et al., 2018) consumption.

During the task, the ambient sounds may not have induced anxiety, resulting in no HRV change. Since anxiety can impact decision-making (Remmers & Zander, 2018), this possibility may also account for the absence of decision-making differences across sound conditions. However, given that previous research suggests sound stimuli can lead to anxiety for autistic individuals (Landon et al., 2016), this would be surprising. It is possible there were differences in anxiety between participant groups at baseline and across the sound conditions that were not reflected through HRV measures. Such a possibility might reflect autonomic dysregulation in autistic individuals (Panju et al., 2015; Truzzi, Setoh, Shinohara & Esposito, 2016) where, despite self-reported negative affect, a physiological response is absent. For example, in Dijkhuis et al.'s (2019) study, there were no significant differences between baseline HRV and HRV during a speaking task in autistic adults, despite participant reports of negative affect during the task. Such dysregulation is problematic because it may result in reduced environmental adaptation, exacerbating feelings of negative affect (Dijkhuis et al., 2019).

Implications

Future research could expand on the present study's paradigm to create a shopping experience with even greater ecological validity. Research could be conducted in a supermarket, though this may improve validity at the cost of experimental control. When Doyle et al. (1999) completed the AE paradigm in a supermarket, they noted several uncontrolled factors, such as the actions of other shoppers.

Several acoustic factors are known to influence sensory reactivity, including unpredictability and frequency (Robertson & Simmons, 2015; Smith & Sharp, 2013). However, in the present study, participants were not specifically asked whether the sounds were distracting to the task or whether certain aspects of the ambient environment were more difficult than others. Additional studies could ask participants to specify which aspects of the ambient environment impacted the task.

Additional physiological measures could be used in future research. For example, pupil diameter, an indicator of arousal, is affected by decision-making uncertainty and pupil-linked arousal also influences decision-making behaviour (Urai et al., 2017). Therefore, this measure may give insights into the relationship between arousal and decision-making behaviour during exposure to ambient sensory environments.

In the present study, participants had high levels of intellectual functioning. Future research could adapt the shopping paradigm to be inclusive of those with intellectual disability, since 50% of autistic people have co-occurring intellectual disability (n=24 studies) (Loomes, Hull & Mandy, 2017).

The context of this study was that of the increasing number of organisations that have begun creating autism-friendly environments. Our qualitative evidence indicated the non-social and social sound conditions were experienced more negatively than the no sound condition for the autistic group, suggesting such autism-friendly changes may help. Research studies should consider alternative quantitative measures and assess the impact of other environmental stimuli, such as lighting or proximity to others, to potentially allow for more detailed recommendations with applications to settings far beyond supermarkets such as classrooms (Zazzi & Faragher, 2018), the workplace (Johnson & Joshi, 2016) and healthcare (Morris, Greenblatt & Saini, 2019; Vohra, Madhavan & Sambamoorthi, 2016). By considering autism as a difference in neurodiversity (Kapp, Gillespie-Lynch, Sherman & Hutman, 2013) and understanding how environments can be altered to promote a good person-environment fit, autistic individuals may be better able to thrive (Lai & Baron-Cohen, 2015; Mandy & Lai, 2016).

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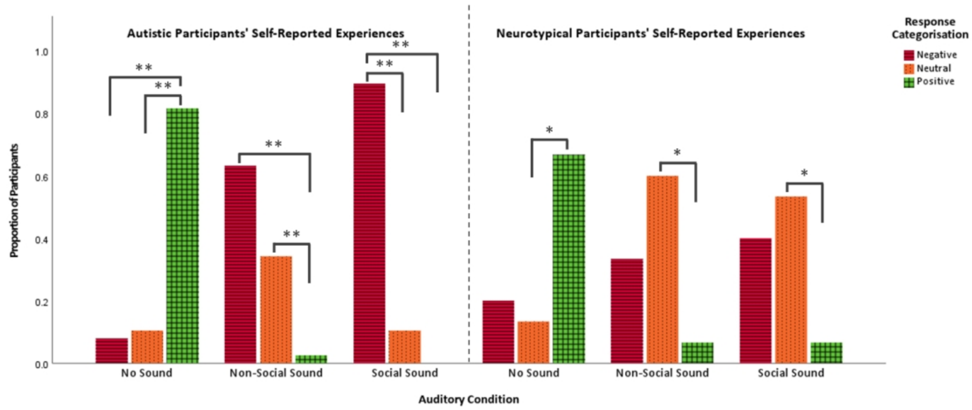

Figure 1""*Proportion of Negative, Neutral or Positive Experiences Reported by Autistic and Neurotypical Participants*""*=p<0.05. **=p≤0.001. All other differences are not statistically significant. Chi-square tests were used to assess significance, except when expected values<5, in which case Fisher's exact test was used.

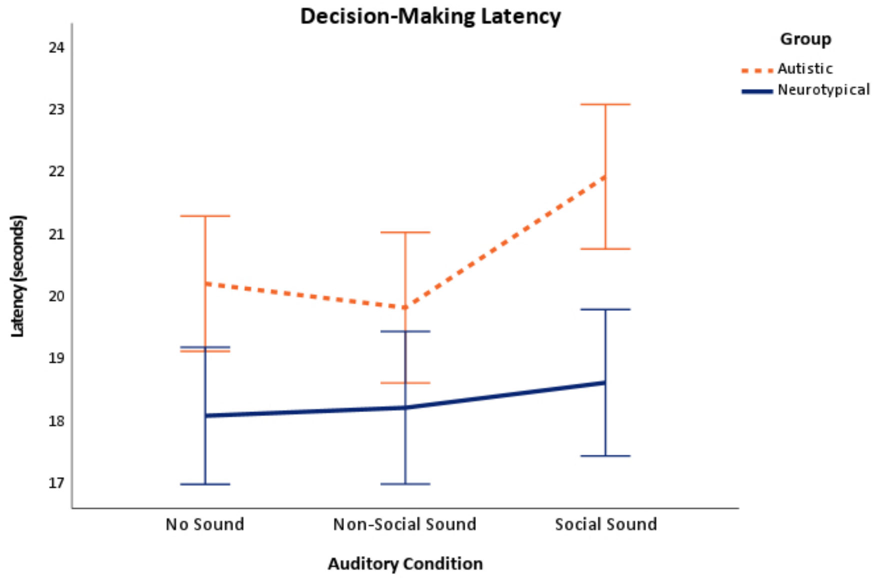

Figure 2""*Decision-Making Latency during No Sound, Non-Social Sound and Social Sound Conditions*""Error bars represent one SE above and below the mean.

267x174mm (72 x 72 DPI)

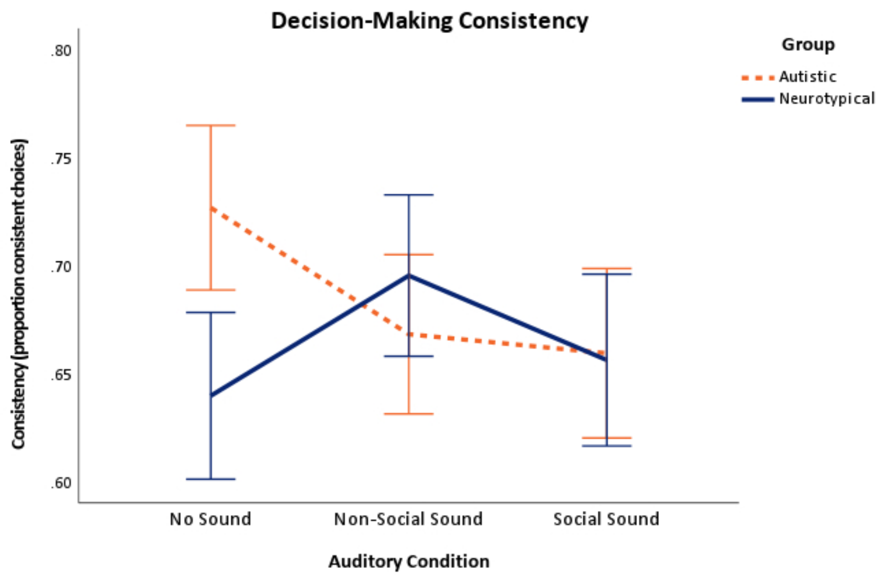

Figure 3""*Decision-Making Consistency during No Sound, Non-Social Sound and Social Sound Conditions*""Error bars represent one SE above and below the mean.

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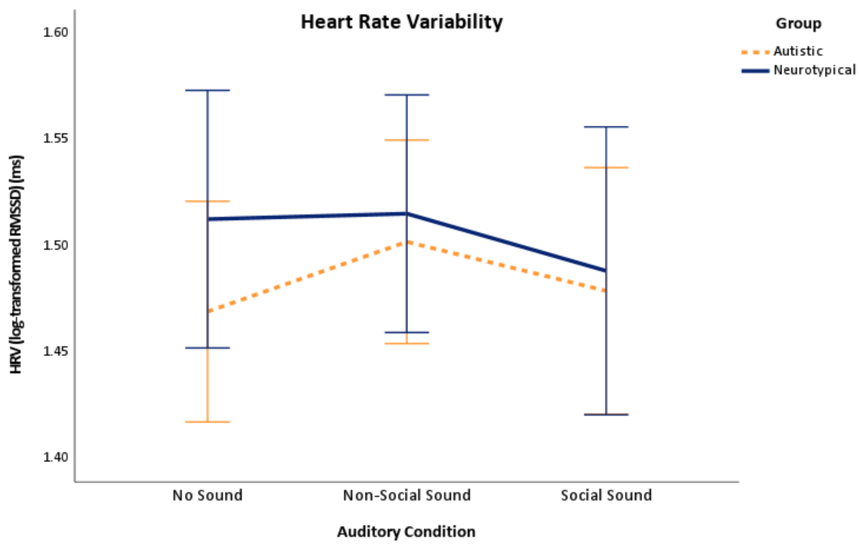

Figure 4""*Log-Transformed Root Mean Square of Successive Differences in Autistic and Neurotypical Groups during No Sound, Non-Social Sound and Social Sound Conditions*""Error bars represent one SE above and below the mean.

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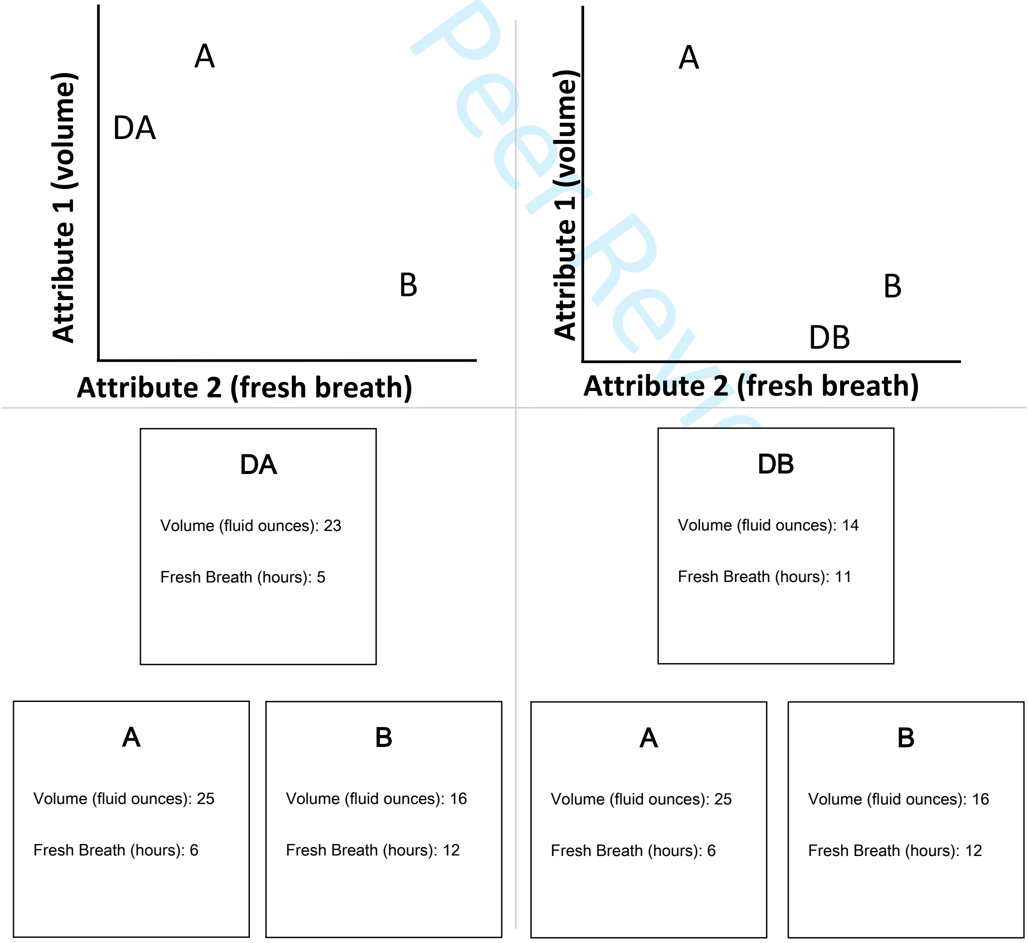
Supplementary Material 1: Attraction Effect Set-Up

Participants are given a choice about a consumer product and are asked to choose one option from a choice of three (a target, a competitor and a decoy). Each option describes the product in terms of two attributes. The target and the competitor options have equally weighted attributes. The decoy option is inferior to the target on both attributes but is not inferior to the competitor. This leads individuals to choose the target more often than the competitor (Figure 1).

Figure 1

Configuration of Options Required to Produce an Attraction Effect (Adapted From Farmer et al., 2017)



The top half of the figure shows the configuration of options required to elicit the attraction effect (where, for both attributes, a greater value is more beneficial). The second half of the figure shows an example pair of attraction effect choices, relating to mouthwash (taken from Farmer et al., 2017)

During the paradigm, individuals first make a choice between options A, B and DA. They later make a choice between options A, B and DB. In the example above, the decoy for A (DA) attracts individuals to choose option A (the target), since DA is inferior to A, both in terms of fresh breath and volume. The decoy for B (DB) attracts individuals to choose B (the target), since DB is inferior to B on fresh breath and volume. If an individual choses A when DA is present and B when DB is present, the attraction effect (AE) has occurred.

Supplementary Material 2: Piloting

Attraction Effect Choices

A pilot was used to determine how many choices were needed to produce a robust attraction effect (AE) and whether there were ambiguities in the description of the options.

Neurotypical individuals made 36 (n=21) or 54 (n=22) AE choices, based on nine supermarket products (orange juice, batteries, printer ink, lemonade, highlighter pens, headphones, lightbulb, mouthwash and paper towels). Six of the products were taken directly from Farmer, Baron-Cohen, & Skylark (2017), while the remaining three (printer ink, batteries and lemonade) were adapted from Farmer et al. (2017). Each option was described in terms of two attributes. Ten attributes and their descriptions were taken directly from Farmer et al. (2017). All other attributes and their descriptions were self-created. Values for AE options were sourced from papers using AE choices (Farmer et al., 2017; Herne, 1999; Wedell, 1991).

Twenty-three participants also indicated whether the descriptions of the choices were ambiguous; 15 completed the 36-choice version and eight completed the 54-choice version.

Number of Choices

Means, SE bars and 95% CIs were compared. For the proportion of AE choices made, SE bars (+/- one SE) and 95% CIs for the 36- (SE bars=0.06-0.10, 95% CIs=0.03-0.13) and 54- (SE bars=0.10-0.14, 95% CIs=0.09-0.15) choice conditions overlapped, suggesting there was no difference between groups in the mean proportion of AE choices.

The proportion of choice pairs where the decoy option was chosen for at least one choice in a pair was assessed. The overlap between the SE bars (36=0.08-0.16, 54=0.05-0.11) and 95% CIs (36=0.03-0.21, 54=0.02-0.14) led to the conclusion of no difference in decoy responding between groups.

The absence of difference between 36- and 54-choice conditions could be due to participants remembering their previous answers. The presentation of the questions allowed participants to navigate to previous questions and directly compare answers, aiding consistent responding. To reduce consistency and increase the AE, several factors were altered in the main study:

1. Each choice was presented on a separate page to reduce direct comparison of answers.
2. Participants could only progress forward, ensuring they could not change their answers.
3. Within each product, choices were randomised so, for each product, all the first choices in a pair occurred before the second choices, reducing the likelihood that participants saw both choices in a pair in succession and could remember their answers.

With these changes, being presented with more choices will increase memory load and likely reduce memory of previous answers. Consequently, it was concluded that 54 choices should be used in the shopping decision-making task because (i) the greater memory demands elicited by making more choices are likely to reduce consistency in responding and (ii) adding more choices did not influence noisy responding.

Ambiguity

Four participants commented about the vagueness of the term ‘quality’. Consequently, descriptions mentioning ‘quality’ were changed in attempt both to increase their ecological validity and reduce their ambiguity.

Four participants noted a specific problem concerning the ‘lifetime’ attribute of a lightbulb, suggesting lightbulbs would be replaced not repaired. Three attribute wordings were changed from ‘repaired’ to ‘replaced’ in an attempt to improve ecological validity.

Auditory Supermarket Environment

Prior to the pilot, 46 sound clips were collected, through both recording sounds directly in a supermarket and retrieving sounds from online sound banks. Participants (n=50) categorised the 46 sound clips as social or non-social.

Sounds with 75% consensus were included in the main study since this percentage represents a large difference from no consensus (Cohen, 1992).

Twelve sounds were categorised as 'social' and 18 as 'non-social' (Table 1). These sounds were included in the social and non-social auditory collages used in the shopping decision-making task. Sixteen sounds did not reach the agreed criterion of 75% consensus, so were not used in the auditory collages.

Table 1

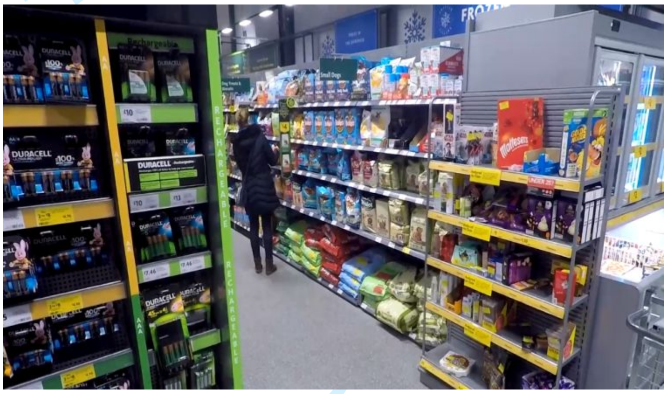
Categorisation of Sound Clips

Social	Non-Social
Baby Babble	Air Conditioning
Background Talking	Stacking Boxes
Background Talking 2	Car Alarm
Bakery Discussion	Checkout Beep
Children	Door Shutting
Children 2	Dropped Box
'Where is the coffee?'	Fans Whirring
Cookies Phone Conversation	Footsteps
Laughing	Footsteps 2
'Where are the prawns?'	Fridge Humming
Salted Butter Phone Conversation	Phone Typing
Scampi Conversation	Rain
	Shopping Basket Squeak
	Sliding Door
	Squeaky Shoes
	Shopping Trolley 2
	Ticking Clock
	Traffic

Supplementary Material 3: Screenshots from the Films shown in the Shopping Decision-Making Task: a) Entrance Film, b) and c) Product Films, d) Exit Film

a)

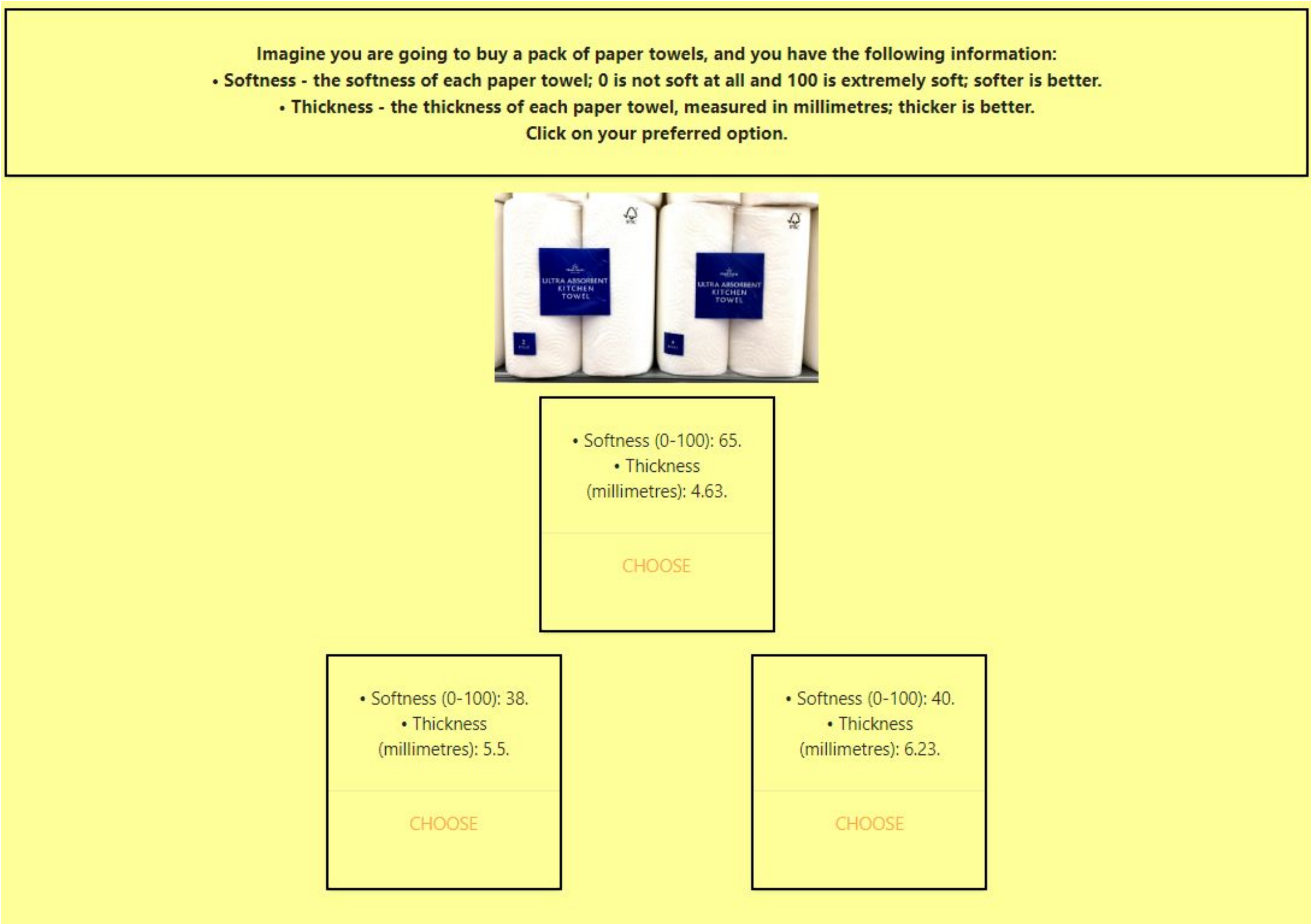
b)



c)

d)

Supplementary Material 4: Example Choice as shown in the Shopping Decision-Making Task



Supplementary Material 5: Participant Self-Reported Ethnicity across Autistic and NT (Neurotypical) Groups

Ethnicity	Autistic Frequency	NT Frequency	Total
White British	31	28	59
Chinese	0	3	3
Asian (other)	0	2	2
White Irish	1	1	2
Black British	1	0	1
British Indian	0	1	1
British Bangladeshi	0	1	1
Italian	1	0	1
Indian	1	0	1
West Indian	1	0	1
White African	0	1	1
Prefer Not to Say	2	0	2
Total	38	37	75

Supplementary Material 6: Self-Reported Medical Diagnoses across Autistic and Neurotypical (NT) Groups for all Diagnoses Reported by at Least Two Participants

Self-Reported Diagnosis	Autistic Frequency	NT Frequency	Total
Anxiety	22	4	26
Depression	20	4	24
Dyslexia	7	0	7
Asthma	2	4	6
Hay Fever	3	2	5
Muscular-Skeletal Diagnoses	1	4	5
Heart Disease Diagnoses	4	1	5
Dyspraxia	4	0	4
High Blood Pressure	2	2	4
Borderline Personality Disorder	3	0	3
Type 2 Diabetes	3	0	3
Hypothyroidism	1	2	3
Attention Deficit Hyperactivity Disorder	3	0	3
Hypermobility	3	0	3
High Cholesterol	1	2	3
Obsessive-Compulsive Disorder	2	0	2
Post-Traumatic Stress Disorder	2	0	2
Bipolar Disorder	2	0	2
Eating Disorder	2	0	2
Sleep Apnea	2	0	2
Epilepsy	2	0	2
Body/Gender Dysmorphia	2	0	2
Irritable Bowel Syndrome	2	0	2
Chronic Obstructive Pulmonary Disease	1	1	2
Tinnitus	1	1	2
None	6	19	25

Participants fall into more than one category if they have more than one diagnosis.

Supplementary Material 7: Number of Autistic and NT (Neurotypical) Participants Self-Reporting Taking Medication

Medication Group	Medication Type	Autistic Frequency	NT Frequency	Total
Psychotropic	Antidepressants	15	3	18
	Anti-Psychotic	5	0	5
	Anti-Anxiety+	3	2	5
	Stimulants	2	0	2
Cardiac	Statins	5	4	9
	Calcium Channel Blocker	2	3	5
	ACE Inhibitor	2	1	3
	Angiotensin Receptor Blocker	2	1	3
	Aspirin	1	1	2
	Beta-Blocker•	1	1	2
	Nitrates	2	0	2
	Anti-Platelets	0	1	1
Hormonal	Thyroxine	1	2	3
	Oestrogen	2	0	2
	Combined Contraceptive	1	0	1
Allergy Medication		2	4	6
Respiratory		3	3	6
Gastro-Intestinal		5	1	6
Vitamin Supplements		3	1	4
Painkillers		1	2	3
Anti-Diabetic		3	0	3
Antibiotics		2	0	2
Hypnotics		2	0	2
Immunosuppressants		1	0	1
Anti-Epileptic		1	0	1
Osteoporosis Treatment		0	1	1
No Medication		8	20	28

Participants fell into more than one category if they were taking more than one medication type.

+=includes two autistic and two neurotypical participants prescribed beta-blockers for anxiety.

•=beta-blockers prescribed for cardiac problems.

Supplementary Material 8: Shopping Product Familiarity, Knowledge and Preference Differences Across Autistic and Neurotypical Groups

Variable	Autistic Frequencies	NT Frequencies	Fisher's Exact Test Value	*p*-value	Significant Post-Hoc Tests
Product Familiarity	**1**=4, **2**=24, **2.5**=0, **3**=10	**1**=0, **2**=30, **2.5**=1, **3**=6	6.27	0.06	
Product Preference	**1**=2, **2**=14, **3**=22, **4**=0	**1**=0, **2**=22, **3**=11, **4**=4	10.71	0.01*	None (for all comparisons, $p \geq 0.58$)
Product Knowledge	**1**=2, **2**=33, **3**=3	**1**=1, **2**=35, **3**=1	1.39	0.61	

Post-hoc tests were calculated using standardized residuals and *p*-values were Bonferroni-corrected.

Product Familiarity/Preference/Knowledge reflect the median scores across all products. Familiarity and knowledge scores can range from 0-3 and preference scores can range from 0-4. A higher score indicates greater familiarity/knowledge/preference.

Under the 'Autistic Frequencies' and 'NT Frequencies' columns, the numbers in bold are the Familiarity/Preference/Knowledge scores and the non-bold numbers reflect the frequency of participants who had each score.

*=$p \leq 0.05$.

Supplementary Material 9: Example Comments by Autistic and Neurotypical Participants Categorised as Negative, Neutral or Positive and the Auditory Condition to Which They Refer

Categorisation	Sound Condition	Example Comments
Autistic Participants		
Negative	No Sound	'Difficult to concentrate as [I] get easily distracted.' 'Still quite difficult. Wanted to make right decisions but didn't know what to judge/base it on.'
	Non-Social Sound	'The worst. Felt so relentless and loud. Continuous.' 'Horrendous. Ridiculous level of noise. Very distracting. Felt under pressure.'
	Social Sound	'Very stressful. Quite on edge. Not easy to concentrate on task, especially [when the] baby [was] crying - couldn't think about anything else.' 'Becoming more and more agitated and irrationally angry. Difficult to concentrate. Had to read information more than once to remember it. Pleased to leave at the end. Not much of an exaggeration of real life.'
Neutral	No Sound	'More straightforward, but a bit eerie.' 'Alright.'
	Non-Social Sound	'Not too bad: could deal [with it].' 'Bit distracting but not too bad. Potentially distracting but didn't worry too much.'
	Social Sound	'Used to blocking stuff out. Marginally more distracting. Brain is programmed to listen to communication, so harder to block out. Easy to block out if not relevant.' '[I] managed to tune it out as [I] knew that's what [I] was meant to do.'
Positive	No Sound	'Fine making decisions. Chilled out.' 'Felt like a normal shopping trip. No impact on task. Felt less stressed.'
	Non-Social Sound	'Surprisingly chilled. Like white miscellaneous noise. Not particularly distracting or stressful.'
Neurotypical Participants		
Negative	No Sound	'Bit strange. Not the way it works.' '[I'm] not used to it being this quiet. [I] had to think more.'
	Non-Social Sound	'The beeps were annoying. I didn't like it.' 'A bit irritating.'
	Social Sound	'Difficult. [You] would listen to conversations in their entirety.' 'The most irritating. [I] had to wait for conversations to finish before carrying on.'

Neutral	No Sound	'Not massively distracting to the task.' 'Fine.'
	Non-Social Sound	'Alright. [I] could cope.' 'Fine. [I didn't] find [the] sounds distracting.'
	Social Sound	'Not too bad. Fairly normal. [It] didn't influence the task.' '[It was] vaguely distracting as the conversations were so audible. But [it was] still easy to focus.'
Positive	No Sound	'A lot easier. More relaxed.' 'Quite peaceful and pleasant.'
	Non-Social Sound	'Most comfortable. [It] seemed more natural. [You] always hear ambient noise in a shop.'
	Social Sound	'[I'm] used to it. The easiest.'

Supplementary Material 10: Decision-Making Latency (ms), Consistency (Proportion of Consistent Choices) and Root Mean Square of Successive Differences (RMSSD; ms) in Autistic and Neurotypical (NT) Groups Across Sound Conditions

Participant Group and Measure	No Sound Mean	No Sound SD	Non-Social Sound Mean	Non-Social Sound SD	Social Sound Mean	Social Sound SD
Autistic Latency	20206	7490.75	19821	8619.45	21922	8100.56
NT Latency	18085	5759.30	18214	6019.27	18616	6022.37
Autistic Consistency	0.73	0.23	0.67	0.25	0.66	0.23
NT Consistency	0.64	0.23	0.70	0.21	0.66	0.26
Autistic RMSSD	35.37	21.88	37.60	24.02	36.81	25.08
NT RMSSD	39.25	21.25	38.23	18.02	38.83	20.06

Supplementary Material 11: Non-Significant Differences in Age, Self-Reported Gender and IQ Between Autistic and Neurotypical Groups in the HRV Analysis

Variable	Autistic Mean	Autistic SD	NT Mean	NT SD	95% CIs	*df*	*t*-value	*p*-value	Cohen's *d*
IQ	114.6	11.33	114.5	9.19	-5.9–6.0	50	0.02	0.99	0.03

Variable	Autistic Frequencies	NT Frequencies	*df*	χ^2 value	*p*-value	Cramer's *V*
Self-Reported Gender	M=12, W=18	M=9, W=13	1	<0.01	0.95	0.009
Age	1=20, 2=10	1=16, 2=6	1	0.22	0.64	0.065

Self-Reported Gender: M=man, W=woman. Age Category: 1=18-49 years, 2=50 years and above.

Supplementary Material 12: HF-HRV (High-Frequency Heart Rate Variability) across Sound Conditions and Participant Groups

HRV was measured through log-transformed absolute power HF-HRV (ms^2) values, since raw data violated the assumption of normality of residuals. Means and standard deviations reported here reflect raw values, but all other values are log-transformed. A non-significant group x sound condition interaction was found [$F(2, 100)=0.82$, $p=0.44$, $\eta^2_p=0.016$], confirming that HRV did not differ between participant groups across no sound (autistic: M=765.07, SD=1009.27; NT: M=720.50, SD=650.79), non-social sound (autistic: M=837.46, SD=1313.46; NT: M=642.90, SD=486.38) and social sound (autistic: M=830.82, SD=1358.79; NT: M=683.92, SD=550.02) conditions. Non-significant main effects for sound condition [$F(2, 100)=1.66$, $p=0.20$, $\eta^2_p=0.032$] and participant group [$F(1, 50)<0.01$, $p=0.96$, $\eta^2_p<0.001$] were also found.

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