Alexithymia is associated with lower confidence in both perceptual and emotion recognition tasks

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Author Note

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Abstract

Emotions play an important role in everyday decision-making, but emotional awareness can vary greatly between people. Alexithymia, a trait characterized by little or no awareness of one's emotions, is broadly associated with poor mental health and increased risk of suicide. Alexithymia is fairly common, affecting as much as 10% of people in Western cultures. Understanding how alexithymia relates to decision-making may therefore have wide-reaching impacts on the quality of life for many individuals. We designed and preregistered a study that examined the relationship between alexithymia and decision-making across different task-types. Data were collected from a community sample ($N = 123$) and participants completed a social, an emotional, and a perceptual decision-making task, as well as a short alexithymia questionnaire. For each task, we considered multiple aspects of the decision-making process, examining participants' accuracy, confidence, and metacognitive ability (i.e. the ability to retrospectively distinguish between correct and incorrect responses). We found no relationship between alexithymia and performance or metacognitive ability in any task. However, alexithymia was negatively correlated with confidence in both the perceptual and emotional tasks. Furthermore, confidence in one's decision was strongly, positively correlated across task types, but both accuracy and metacognitive ability showed no relationship between tasks. These results suggest that confidence may be a trait-like, affective component of decision-making, while performance and metacognitive sensitivity appear more task-specific. Furthermore, our results challenge the current limitations of the alexithymia construct, suggesting that alexithymia may have consequences on cognitive processes beyond emotion recognition alone.

Keywords: alexithymia, confidence, metacognition, uncertainty, decision-making

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Imagine that it is late at night and you left your window open when you went to bed. You are awoken when you hear a sound – from somewhere outside, you hear a woman scream. Living in a big city, hearing people yelling or screaming is not that uncommon, but this time you are not sure whether it sounded more like she was having fun with her friends or like she was in danger. You need to decide whether to call emergency services. While in abstract the answer may seem obvious, in the moment there are a number of factors that may alter how you perceive the uncertainty. You might feel scared on the woman's behalf, or you might prematurely feel guilty for not calling and decide to call to resolve your guilt. Alternatively, you might be afraid of the uncertainty and paralyzed by the many actions available to you. Now imagine that you don't have access to your emotions at all – you cannot tell what you are feeling. How might that change your experience of the situation and the decision you make?

Emotions play a powerful role in our decision-making, acting as motivational forces that shape our perceptions of value (Cardinal, Parkinson, Hall, & Everitt, 2002; Smith, Killgore, & Lane, 2017) and predispose us to particular sets of actions (Bradley, Codispoti, Cuthbert, & Lang, 2001). As one might expect, emotional awareness varies considerably across people (Smith, Killgore, & Lane, 2017). Alexithymia is a sub-clinical syndrome characterized by a restricted emotional life, an impoverished fantasy life, and a difficulty putting words to feelings (Sifneos, 1973). There are multiple models of alexithymia (see Vorst & Bermond, 2001 and Preece et al., 2018), but here we focus on the Toronto Model (Taylor, Bagby, & Parker, 1991), due its simplicity and high frequency of adoption in the literature. This version of the Toronto Model considers three facets of alexithymia: Difficulty Identifying Feelings (DIF), Difficulty

Describing Feelings (DDF), and a tendency to avoid introspection (i.e. externally-oriented thinking; EOT). Individuals with high levels of alexithymia lack the ability to engage in emotional introspection, which may alter the role emotions play in their decision-making.

While alexithymia is not necessarily a clinical diagnosis, it is consistently associated with poorer wellbeing across mental, physical, and social health. In particular, higher levels of alexithymia have been associated with depression (Li et al., 2015), eating disorders (Westwood, Kerr-Gaffney, Stahl, & Tchanturia, 2017), substance abuse (Ghalebani & Besharat, 2011; Giannini, 1995), increased risk of suicide (De Barardis et al., 2017), unusual patterns of experiencing and reporting illness (Lumley et al., 1996), aversive personality traits (e.g. the “Dark Triad”; Jonason & Krause, 2013), and both impoverished systems of social support and lower perceived social support (Lumley, Stettner, & Wehmer, 1996). The direction of causality in these relationships has not been definitively demonstrated, but many researchers have suggested that alexithymia exacerbates, if not causes, important components of these problems. Taking into account that an estimated 10% of adults in Western European countries have high levels of alexithymia (Salminen et al., 1999; Kokkonen et al., 2001), it becomes evident that alexithymia has a meaningful impact on the health and wellbeing of many people.

The effects of alexithymia on emotion perception seem to extend beyond just emotional introspection and into emotion recognition more broadly. Behavioral studies of alexithymia have demonstrated that alexithymia is related not only to the ability to specify one’s own emotions (Aaron, Snodgrass, Blain, & Park, 2018), but also to the ability to recognize emotions in others. Higher alexithymia is associated with poorer performance on a variety of emotion recognition tasks at both the conscious and subconscious level, although the effect sizes for these relationships are usually modest and do not always replicate (Donges, Kersting, & Suslow,

2014). One of the most common of these emotion recognition tasks requires participants to identify emotional facial expressions, either by selecting a label from a set of descriptors or choosing one themselves (Grynberg et al., 2012). A review by Grynberg et al. (2012) concluded that, even after accounting for the potential attributions of depression and anxiety, individuals with high alexithymia are consistently less accurate in these emotional identification tasks. Altogether, these studies seem to demonstrate a consistent association between alexithymia and deficits in emotion recognition.

However, while the relationship between alexithymia and accuracy in emotional identification tasks has been thoroughly documented, the mechanisms underlying decision-making in these tasks remain largely unexplored. In particular, there has been relatively little research on the relationship between alexithymia and decision-making under uncertainty, despite existing research suggesting a relationship between these two constructs. In particular, multiple studies have shown that alexithymia is positively correlated with self-reported intolerance of uncertainty, a trait characterized by the rejection of and discomfort with ambiguity (Abbate-Daga et al., 2015; Maisel et al., 2016; South & Rodgers, 2017). The authors of these studies suggested that the relationship between alexithymia and intolerance of uncertainty may cause or otherwise exacerbate anxiety and other clinical symptoms. Alexithymia has also been directly associated with lower self-reported confidence in emotional perception judgements (i.e. higher subjective uncertainty), even in the absence of a relationship with task accuracy (Lorey et al., 2012). These findings suggest that the ability, or inability, to identify and interpret one's emotions may be linked to how one perceives and reacts to uncertainty.

Given that emotions exert influence on processes of evaluation and action-selection, it is reasonable to expect that alexithymia may be linked to decision-making beyond emotion

recognition tasks. Although research on this topic is scant, Jacob and Hautekeete (1998) noted that individuals with high alexithymia outperformed individuals with lower alexithymia on elimination trials in a non-emotional memory task. This led the authors to suggest that individuals with high levels of alexithymia require more information to endorse an observation than individuals with lower levels of alexithymia. While this finding has not been replicated, it does have an appealing logical flow: if emotions provide information to a decision-maker, then those who cannot access their emotions may require more evidence in order to compensate. Alexithymia, therefore, may be associated with a greater need to seek-out information in order to compensate for the absence of emotional information. To the extent that emotional information can affect decisions beyond emotion classification, this could mean that alexithymia may affect decision-making in a wide variety of content domains, not just ones related to emotional processing. Surprisingly, despite the fact that it is commonly accepted that emotions play an important role in decision-making in general (Inzlicht, Bartholow, & Hirsch, 2015; Lerner, Li, Valdesolo, & Kassam, 2015), there is a noticeable dearth of studies that examine how one's awareness of their emotions relates to decision-making across content domains. Looking at decision-making across content domains (e.g. perceptual, emotional, social) and across levels of alexithymia may provide valuable insight into the role that consciously-perceived emotions (i.e. feelings) affect decision-making.

Beyond its effects on decisions directly, alexithymia may influence the way people evaluate their decisions. The ability to identify and evaluate one's cognitions and memories is a critical component of metacognition known as "monitoring" (Koriat, 2007). Recall that alexithymia is defined, in part, by an avoidance of introspection (e.g. EOT) and is associated with both greater uncertainty in emotion tasks and discomfort with uncertainty in general.

Together, these associations suggest the possibility that alexithymia is associated with a general deficit in metacognitive monitoring. A diminished capacity for recognizing one's own thoughts, i.e. poorer metacognitive monitoring, could in turn diminish emotional awareness due to a reduced ability to engage with and reflect on conscious feelings. Alternatively, an inability to identify emotions could also reduce the quality of metacognitive perceptions. For example, if an individual is unable to read their emotional state when reflecting on past actions, they will miss information about the impact of that action, namely its hedonic value. Moreover, if a person's emotions continue to influence their decisions even when they cannot identify them, that person will be unable to recognize and account for the influence of emotions on their decisions. While inaccurate self-reflection is likely to cause problems eventually, it has been suggested that such avoidance of emotional introspection in alexithymia may act as a coping mechanism to reduce proximal discomfort associated with emotion (Segerstrom & Smith, 2019). However, the connection between alexithymia and metacognitive monitoring ability has not been rigorously studied. Examining the interplay of alexithymia and metacognitive ability could provide useful insights into the mechanisms underlying both phenomena.

The present study was designed to address the relationship between alexithymia and decision-making across social, emotional, and perceptual task types. To this end, participants completed the Trust Game (Berg et al., 1995), the Revised Reading the Mind in the Eyes Test (RMET; Baron-Cohen et al., 2001), and a Random Dot Kinematogram task (here called the "Dot Task"; Newsome & Pare, 1988) to address each of these decision-making domains, respectively. By collecting confidence ratings and using principals of signal detection theory (SDT), we were able to measure metacognitive uncertainty in the Dot Task and RMET. By assessing accuracy, confidence, and metacognitive ability across these tasks, we were able to provide an unusually

comprehensive examination of the cognitive mechanisms implicated in alexithymia and decision-making, and whether the influence of alexithymia extends beyond the processing of emotional information. Furthermore, we were able to analyze the relationships between these measures across domains of decision-making.

Methods

Preregistration

The study design, hypotheses, and analyses were preregistered on the Open Science Framework (https://osf.io/r3hsp/?view_only=7fe1c8ffb2de451d8e24779ac73e1664). Given our focus on alexithymia, our preregistration did not include hypotheses about the relationships between decision-making tasks, although it did include analyses for this purpose. Non-preregistered analyses, such as the effect of age and gender on behavior, are noted as such in the manuscript and treated as exploratory. All exclusion criteria were also included in the preregistration.

Hypotheses

Alexithymia and Emotional Decision-Making

As reviewed above, previous literature suggests that it is reasonable to expect self-reported alexithymia to be negatively correlated with performance and confidence on emotion recognition tasks (Donges et al., 2014; Grynberg et al., 2012; Lorey et al., 2012). Hence, we predicted that self-reported alexithymia would be negatively correlated with accuracy and confidence on the RMET. We also predicted that alexithymia would be correlated with metacognitive sensitivity, but we had no strong directional expectations. However, we noted that, if increasing levels of alexithymia reduce introspection for emotional information, we would

expect to find a negative correlation between metacognitive sensitivity and TAS-20 scores. After all, if one is not willing or able to reflect on their experiences with emotional information they are unlikely to produce accurate evaluations of their behavior. In general, the prediction that alexithymia would affect multiple levels of emotional decision-making is consistent with the general conceptualization of the alexithymia construct as a broad inability to process emotions.

Alexithymia and Perceptual Decision-Making

Although alexithymia has not been traditionally associated with perceptual decision-making, its association with higher levels of intolerance of uncertainty and potentially a greater need for information suggest that it may affect decision-making beyond just the social and emotional domains. If alexithymia interferes with the ability to manage uncertainty, either by overwhelming the observer or preventing them from accessing motivational information, it could disrupt performance accuracy even in perceptual tasks. However, the traditional conceptualization of alexithymia would suggest that its influence is likely to be emotion-specific. Given that past research has not thoroughly examined the scope of alexithymia's impact, we presented both of these possibilities as hypotheses in our preregistration.

If the association between alexithymia and confidence is not emotion-specific, it may affect confidence in perceptual decisions as well emotional ones. While this suggests a possible relationship between alexithymia and confidence in perceptual decision-making, we made no predictions regarding the direction of this relationship, given that alexithymia has not been traditionally associated with perceptual processing. However, in an attempt to replicate past research (Jacob & Hautekeete, 1998) on alexithymia and uncertainty management, we predicted that self-reported alexithymia would be associated with more rigorous decision-criteria, an index

of the amount of information required for an individual to endorse a particular response.

Altogether, we expected that alexithymia would be associated with individual differences in the subjective experience and management of uncertainty.

As reviewed above, alexithymia is associated with a reduced tendency to reflect on one's emotional experiences. Interestingly, previous research has not thoroughly tested whether this absence of self-reflection is truly emotion-specific, or whether it may be associated with a more general depression of metacognitive abilities. Thus, if alexithymia was negatively correlated with metacognitive sensitivity in the RMET, we expected that it would either have no relationship to metacognitive sensitivity in the Dot Task, or be negatively correlated with it. These outcomes reflect an emotion-specific and a metacognitive deficit account of alexithymia, respectively. In examining this relationship, we hoped to not only gain insight into the role of alexithymia in metacognitive processing, but also into the relationship between metacognitive ability across types of task content.

Alexithymia and Social Decision-Making

Constructing strong hypotheses about the effects of alexithymia on social decision-making was made difficult by the fact that the root cause underlying the relationship between poorer social well-being and alexithymia remains unclear. Although alexithymia has been associated with poorer empathetic skills, its relationship with altruism and trust has not been thoroughly examined. Thus, there is only partial support for the hypothesis that alexithymia would be associated with lower trust and reciprocity. Additionally, while alexithymia has been associated with difficulties in emotional theory of mind (e.g. Oakley et al., 2016), it is unclear how it relates to general theory of mind. Therefore, there is also only partial support for the

hypothesis that alexithymia would be associated with poorer accuracy in the prediction of others' behavior. Overall, while we predicted that alexithymia may affect both trust and reciprocity decisions and the accuracy of social predictions, we did not believe there was sufficient support to warrant strong directional expectations. Likewise, we expected that confidence in the prediction of others' behavior on the Trust Game may be correlated with alexithymia, but did not specify a direction.

Ethics

This study was approved by the University of Minnesota's Internal Review Board (STUDY00005811). All participants provided informed consent.

Participants

We conducted an *a priori* power analysis using G*Power3 (Faul, Erdfelder, Lang, & Buchner, 2007) to determine the appropriate sample size required to detect a medium-sized correlation ($r = .30$) using a significance level of $\alpha = .05$. The results showed that a sample size of 134 participants was required to achieve a power of .95.

We recruited and collected data from participants in the Driven 2 Discover (D2D) facility at the 2019 Minnesota State Fair. The D2D facility is an open-air, single-room building with good indoor lighting and fans. The facility is not temperature-controlled, but the weather was mild during the three days we collected data at the fair ($M = 74.6^{\circ}\text{F}$, $SD = 2.52^{\circ}\text{F}$). Fair-goers were able to wander freely through the building and participate in studies that interest them after listening to a brief description from the experimenter. We collected data from up to six participants at a time, seated at two connected tables. Each participant was provided a laptop and

was separated from other participants by a cardboard divider to prevent participants from seeing each other's responses.

Given that data collection was a rapid process with little time between participants to check the quality of collected data, we preregistered our intention to collect data from 150 participants and only analyze data from the first 134 eligible participants. We required that participants be at least 18 years of age, have normal or corrected-to-normal vision, and not be visibly intoxicated. Additionally, participants who both missed 50% or more of easy practice trials and performed below 60% correct across all trials of the Dot Task were excluded on the basis that they did not understand the instructions, could not perform the task, or were simply not paying attention.

We collected data from 150 participants who were compensated with a Minnesota drawstring-backpack and a chance to win a \$100 Amazon gift card, contingent upon their behavior in one of the experimental tasks (the trust game, see details below). After applying our inclusion criteria, 123 eligible participants remained, of which 56.9% identified as female, 40.7% as male, 1.6% as non-binary, and less than 1% as gender-fluid. Additionally, the participant pool was fairly age diverse ($M = 45.6$, $SD = 17.1$) and predominantly self-identified as White (84.5%) or Asian (11.4%), with the remaining 4% identifying as Black or African American or as mixed race (Black or African American and White or Asian and White).

Design

We analyzed participants' performance, confidence, and metacognitive ability scores across different tasks and alexithymia scores. Participants completed the Toronto Alexithymia Scale (TAS-20) questionnaire and three decision-making tasks: a Random Dot Kinematogram

task which we called the Dot Task (Newsome & Paré, 1988), a facial emotion recognition task called the “Reading the Mind in the Eyes Task” (RMET; Baron-Cohen et al., 2001), and a social-economic decision game called the Trust Game (Berg, Dickhaut, & McCabe, 1995). The order of the tasks was counterbalanced across participants such that each permutation of tasks was run on about 22 participants distributed as evenly as possible throughout the testing process.

Additionally, half of participants completed the TAS-20 before the decision-making tasks and the other half completed the TAS-20 afterwards to account for potential order effects. The order of the TAS-20 was evenly distributed across counterbalancing conditions.

In order to examine multiple aspects of decision-making, we accounted for task performance, participants’ confidence about their choice (subjective uncertainty), and metacognitive ability in each task. In the RMET and Dot Task, we used percent-correct scores to measure participants’ performance and trial-by-trial confidence ratings to measure participants’ subjective uncertainty. We also used three different established measures of metacognitive ability: median confidence ratings, metacognitive sensitivity, and metacognitive efficiency (see Fleming et al., 2014). Metacognitive sensitivity provides an index into how well an individual can distinguish between their own correct and incorrect answers and metacognitive efficiency does a similar calculation that adjusts for the participant’s ability to perform the task, which otherwise muddies the metacognitive sensitivity index (Maniscalco et al., 2012). Unfortunately, based on the way our tasks were constructed only the RMET and Dot Task had data types amenable to the metacognitive sensitivity analysis we employed, area under the Type-2 receiver operating characteristic curve (AUROC2), and only the Dot Task’s data was amenable to the metacognitive efficiency analysis (meta- d' to d' ratio).

Given that participants did not make multiple predictions about others' behavior or rate their confidence in those predictions, performance and confidence in the Trust Game could not be assessed in the same way as in the RMET or Dot Task. Moreover, metacognitive sensitivity could not be calculated at all, as it is a summary of the alignment of performance and confidence over multiple trials. However, we were still able to compare trust, reciprocity, prediction accuracy, and prediction confidence in the Trust Game to performance and confidence in the other tasks. In particular, we compared prediction accuracy to percent-correct scores and prediction confidence to median confidence in the other tasks. All of these measures across all tasks were correlated with TAS-20 scores to examine the relationship between alexithymia and decision-making across these three domains.

Tasks

Dot Task

The Random Dot Kinematogram (RDK) task, here called the Dot Task, is a visual perception task that requires the observer to identify the direction of coherent movement of dots on a screen (Newsome & Parè, 1988). The participant sees a circular window full of dots, some of which move coherently in one direction and the rest of which move in random directions. The difficulty of the task can be modulated by changing the ratio of coherent dots (signal) to random dots (noise).

Our version of the Dot Task was generated using the Random Dot Kinematogram tool in PsychoPy Version 3.1.2. Participants completed the task on a laptop computer with a 14-inch display running at 60 Hz. The laptop was placed on a level surface at the same height for all participants. At the beginning of each trial, 500 dots were placed randomly within a circular field

in the center of the display and each dot survived for five frames (83 ms). The kinematogram was on the screen for 500 ms and was preceded and proceeded by a 500 ms inter-stimulus interval depicting a crosshair in the center of the screen.

The coherent-motion dots moved either left (180°) or right (0°) and the proportion of coherent to random dots varied across three different signal-to-noise ratios (SNRs) in the practice trials (1.0, .8, .5) and four different SNRs in the experiment trials (.05, .25, .45, and .65). The order of the practice trials was predetermined: two trials of each SNR in descending order, one for each direction of coherent movement. If they needed more practice, participants could repeat the practice trials *ad infinitum*; only their last round of practice trial data was considered for inclusion criteria. Trial order in the experimental trials was randomly generated for each participant using the `random.shuffle()` function in Python.

During each experimental trial, participants saw the dot motion described above, followed by the question “In what direction were the coherent dots moving?” and the two possible answer options (left or right). To answer, participants pressed the left arrow on the keyboard to indicate leftward motion, or the right arrow to indicate rightward motion. After providing an answer, participants saw an eight-point Likert scale and the question “How certain are you about your answer?”

Each participant completed a total of 126 experimental trials. We excluded the first six trials from analysis to give participants a chance to acclimate to the experimental trials. These first six trials included the same direction and SNR paired conditions across participants, but were presented in a random order for each participant. The remaining 120 trials included fifteen instances of each possible direction-SNR pair, for a total of 30 trials at each SNR level.

Revised Reading the Mind in the Eyes Test (RMET)

The RMET was designed by Baron-Cohen et al. (2001) as a measure of social sensitivity, although subsequent studies have suggested that it is more appropriately viewed as a test of emotional expression recognition (Oakley, Brewer, Bird, & Catmur, 2016). The test consists of 36 photos of actors' faces, cropped so that only the eyes are visible to the observer. Each image was presented with four answer-options, all with a consistent emotional valence (e.g. despondent, dubious, horrified, irritated) and the participant was asked to identify the best descriptor for the face. All participants had a glossary of word definitions available to them, so verbal proficiency should not have had an effect on RMET scores. In our version of the RMET, we added an eight-point Likert Scale after each trial and asked participants to rate how certain they felt about their answer.

Trust Game

Our social decision-making task was a modified version of the one-round "Trust Game" developed by Berg, Dickhaut, & McCabe (1995). In our task, participants played to win tickets they could put in a prize drawing for the chance to win a \$100 Amazon gift card. In the first stage of the Trust Game, each participant played the investor role. The investor was given five tickets and was asked how many of their tickets they would give to a trustee. Since there is a risk that the trustee will not give anything back, the amount sent by the investor is a positive expectation in the face of social uncertainty, which has been conceptualized as trust (Guseva & Rona-Tas, 2001). The investor was told that the trustee started with 0 tickets and would receive three times as many tickets as the investor gave them. Additionally, the investor was told that the trustee was a real person that had completed the study.

After making their investment decision, participants were asked to rate how many tickets they expected the average trustee to return when given the maximum number of tickets as well as their confidence in this prediction. These answers provided us with a proxy of prediction accuracy (i.e. the absolute difference between the expected and actual average returned amount when the trustee was given 15 tickets) and a measure of subjective uncertainty surrounding one's social judgement (i.e. the confidence rating). In practice, correlations between participants' TAS-20 scores and their prediction errors (observed – predicted number of tickets) were identical to correlations using TAS-20 scores and participants' predictions, since the “observed” value was the average of the same Trustee decisions for all participants. Nonetheless, it is easier to interpret the extent to which individuals' predictions strayed from the observed average when using the prediction error scores, so our analyses use this measure when discussing Trust Game performance.

Participants then completed five rounds of the Trust Game as the trustee – one for each possible number of tickets they could have been given by the investor, other than zero (in a design similar to Baran et al., 2009). Prior to this point, participants were not aware that they would play both as the trustee and the investor. This was done in order to minimize any effect of playing investor choices related with knowing that one will play both roles. The participants' answers from both the investor and trustee roles were entered into a database and used to determine future participants' outcomes of the Trust Game. Each participants' outcome was determined by random matching them with a past participant, then randomly choosing between either the investor or trustee role to determine the final payout. Thus, there was no participant deception (as participants were indeed matched with other players) and payment for the trust

game, in the form of drawing tickets, was dependent on participants' choices and the ones of the partner they matched with.

20-Item Toronto Alexithymia Scale (TAS-20)

The TAS-20 is one of the most commonly used measures of alexithymia in the field due to its strong psychometric properties (Preece et al., 2017; Bagby, Parker, & Taylor, 1994). It measures three facets of alexithymia: difficulty identifying feelings (DIF), difficulty describing feelings (DDF), and externally-oriented thinking (EOT). Participants endorse items on the TAS-20 using a five-point Likert scale, thus the test has a maximum score of 100 and an expected mean of 52.7 ($sd = 12.5$; Kooimana, Spinhoven, & Trijsburg, 2002). Many researches use the provided cut-offs for high (≥ 61) versus low (≤ 51) alexithymia, however its creators note that the TAS-20 scores are best conceptualized as continuous (Taylor et al., 1988). Hence, here we are using the scores obtained on the TAS-20 as a continuous measure rather than dividing people into groups.

Data Analysis

Signal Detection Theory

Signal Detection Theory (SDT) is an approach to measuring how well an individual is able to differentiate between a signal (i.e. a particular pattern) and noise (i.e. a random pattern, background activity). It does this by designating parameters for an observer's internal representation of evidence for a particular stimulus category and their criterion for the amount of information needed to make a categorization decision (i.e. the *decision criterion*). In the context of perceptual research, psychologists have used this approach to determine the ability of

participants to categorize different stimuli. This type of observation categorization is referred to as a “Type 1” task (Maniscalco & Lau, 2012). One of the advantages of SDT is that it allows to distinguish between a participant’s response bias and a participant’s sensitivity, d' (i.e. ability to discriminate between stimuli; Anderson, 2015; Maniscalco & Lau, 2014). A detailed explanation of Signal Detection Theory is beyond the scope of this paper, and the authors encourage curious readers to examine this methodological approach on their own (Anderson, 2015; Green & Swets, 1966)

Metacognitive Sensitivity

The idea of sensitivity from Type 1 task performance can be applied to examine the extent to which a participant’s confidence aligns with their performance (i.e. the Type 2 task). Sensitivity in a Type 2 task is called “metacognitive sensitivity”, because it measures how well an individual is able to distinguish between their incorrect and correct decisions, an ostensibly metacognitive task. There are many ways of approaching the measurement of metacognitive sensitivity, which are well-reviewed by Fleming and Lau (2014). In some cases, the assumptions of SDT cannot be met (e.g. in tasks with more than 2 choices) and a different measure of metacognitive sensitivity must be used. In our study, we use the Area Under the Type 2 ROC Curve (AUROC2) as an approximation for metacognitive sensitivity in a four alternative forced-choice task and compare it to AUROC2 in the Dot Task (Galvin, Podd, & Whitmore, 2003; Fleming & Lau, 2014). If a participant was randomly guessing, the AUROC2 score should be .50. The AUROC2 score increases to a maximum of one as participants become more accurate in their metacognitive judgements (i.e. their confidence scores are higher for correct

answers and lower for incorrect answers). Thus, AUROC2 provides an easily interpretable measure of a participant's metacognitive sensitivity.

Metacognitive Efficiency

Finally, for tasks which meet the assumptions of SDT theory one can obtain an even more accurate measurement of metacognitive ability. Due to the nature of the calculations of metacognitive sensitivity, task performance always confounds the measure such that participants who perform better on the task will always have slightly higher metacognitive sensitivity scores. Maniscalco and Lau (2012) developed a measure to mitigate this confound by comparing their measure of metacognitive sensitivity (meta- d') to participants' Type-1 sensitivity scores (d') in either a ratio (meta- d'/d') or subtraction (meta- $d' - d'$) form. This measure, which Fleming and Lau (2014) dubbed "metacognitive efficiency", represents the amount of information an individual's confidence carries about their performance, given their level of performance in the task. By accounting for the participant's ability to perform the task, metacognitive efficiency provides a cleaner measure of participants' metacognitive ability.

Results

Descriptive Statistics

TAS-20

The TAS-20 demonstrated good internal reliability (*Cronbach's* $\alpha = 0.84$) and a mean and standard deviation of total scores that was similar to, although slightly below, previously established norms ($M = 42$, $SD = 11$).

Decision-Tasks

Participants' average performance on the Dot Task increased with the signal-to-noise ratio (SNR), ranging from about 55% to 77% correct (see Supplementary Table 3). In a similarly intuitive pattern, median confidence also increased linearly across SNR levels (see Supplementary Materials). Participants scored an average of 74.1% correct on the RMET ($SD = 11.0\%$), much higher than chance (25%), with a median confidence rating of six across trials. This level of performance was comparable to that on the higher SNRs of the Dot Task. In the Trust Game, participants invested an average of 3.20 tickets ($SD = 1.35$), slightly more than half of their endowment. When asked to predict how many tickets would be returned by the average person who received 15 tickets (i.e. got all the 5 tickets from the investor, which were then tripled), participants guessed an average of 6.16 tickets with a median confidence rating of four. Different average returns for each possible Trust Game scenario can be found in Supplementary Table 1.

Alexithymia and Decision-Making

Alexithymia and Task Performance

We hypothesized that alexithymia would be negatively correlated with task performance on the RMET, but, contrary to our prediction, a Spearman correlation revealed no relationship between TAS-20 scores and percent-correct on the RMET ($r = .014, p = .88$; see Figure 1A).

With regard to perceptual decision-making, we predicted that alexithymia would either show no relationship to performance or be negatively correlated with it; the former hypothesis representing an “emotion-specific” conceptualization of the trait. We found that TAS-20 scores showed no relationship to percent-correct on the Dot Task both when collapsed across SNRs ($r = .024, p = .79$) and when SNRs were considered separately (see Figure 2, top). Furthermore, an

exploratory analysis revealed there was no relationship between Type-1 sensitivity (d') scores and TAS-20 scores, indicating no relationship between alexithymia and participants' ability to discriminate between signal and noise on the Dot Task ($r_{.05, .25, .45, .65} = .079, .075, -.018, .0124$; all $p > .38$).

Finally, we found no correlation between TAS-20 scores and the accuracy of participants' predictions in the Trust Game ($r = -.084, p = .36$). Overall, alexithymia was not associated with performance in any of the tasks even, most surprisingly, the emotion identification task. Thus, neither our emotion-specific nor our general-effect hypotheses regarding alexithymia and performance were supported by the data.

Alexithymia and Trust Game Decisions

While we expected that alexithymia may impact social decision-making via reduced empathy, we found no support for this hypothesis in our data. Spearman correlations revealed no relationship between TAS-20 scores and reciprocity, as measured by the return ratio at the maximum investment amount ($r = -.003, p = .97$) and by the average return ratio ($r = .027, p = .77$). There was a negative correlation between TAS-20 scores and number of tickets invested in the Trust Game, but this relationship failed to reach significance ($r = -.17, p = .058$). Contrary to expectations established by previous research that has associated alexithymia with poorer social relationships, our results failed to find a correlation between alexithymia and social decision-making within a trust game.

Figure 1. Spearman correlations between TAS-20 total scores and (A) performance, (B) median confidence, and (C) metacognitive sensitivity (AUROC2) in the RMET. Interestingly, this suggests that at higher levels of alexithymia participants are less confident in their performance, despite having no difference in their actual ability to perform the task.

Figure 2. Spearman correlations between TAS-20 scores and Dot-Task performance (top), confidence (middle), and metacognitive sensitivity (bottom). The SNR levels increase from left to right. TAS-20 scores showed no relationship to performance or metacognitive sensitivity in the dot task. Confidence in the Dot Task was negatively correlated with TAS-20 scores across all SNR levels, although this was only significant when the SNR was .65.

Alexithymia and Confidence

We hypothesized that alexithymia would be negatively correlated with confidence in our emotional task. Furthermore, based on findings linking alexithymia to uncertainty management more broadly, we predicted that alexithymia would be correlated with confidence in the perceptual and social tasks, but did not specify any directional expectation. In support of this first prediction, Spearman correlations revealed a significant, negative relationship between TAS-20 scores and median confidence ratings on the RMET ($r = -.19, p = .032$; see Figure 1B). Similarly, alexithymia was negatively correlated with confidence at all four SNRs of the Dot Task, although it only reached significance at the highest SNR ($r = -.24, p = .0088$; see Figure 2, middle). After collapsing across SNRs, the correlation remained negative, but failed to reach significance ($r = -.15, p = .094$). In contrast to our hypothesis regarding the relationship between alexithymia and confidence and social decision-making, there was no correlation between TAS-20 scores and participants' confidence in their Trust Game predictions ($r = -.029, p = .75$). It should be noted, however, that unlike the other two confidence scores, the Trust Game confidence score was collected from a single point rather than from a collection of repeated responses. Altogether, these results suggest that alexithymia may be associated with a paucity of confidence in decision-making across content domains, at least when multiple confidence ratings are collected.

To further analyze the relationship between alexithymia and confidence, we performed exploratory *post-hoc* Spearman correlations between the TAS-20 subscales and confidence on each of the tasks. All three subscales of the TAS-20 showed no relationship to Trust Game confidence (all $p > .50$). On the RMET, the DIF subscale was significantly, negatively correlated with confidence ($r = -.24, p = .0076$), but DDF and EOT showed no relationships ($p > .16$). This

effect remained significant after a Bonferroni correction to account for the multiple subscale comparisons (adjusted $\alpha = .017$). Finally on the Dot Task, after controlling for 12 comparisons (three subscales across four SNRs; $\alpha = .004$), the DIF subscale was significantly, negatively correlated with confidence on the .25, .45, and .65 ($r_{.25}, r_{.45}, r_{.65} = -.27, -.30, -.32$; $p \leq .003$). Both DDF and EOT showed no correlation with confidence in the Dot Task (all $p > .20$). Higher alexithymia scores were thus associated with lower confidence on both the RMET and the Dot Task, a relationship which seems to be driven by the DIF subscale of the TAS-20.

Alexithymia and Decision Criteria

We predicted that alexithymia would be associated with more rigorous decision-criteria, reflecting a need for more evidence in order to make a categorization decision (see methods). Participants' TAS-20 scores showed no correlation with participants' decision criterion, when the Dot Task was separated by SNR (all $p > .12$). Furthermore, an exploratory Spearman correlation revealed no correlation between TAS-20 scores and decision criteria calculated across all SNRs ($r = -.11, p = .19$). Thus, contrary to our hypothesis, there was no indication that alexithymia had any effect on the decision criterion an individual uses to distinguish signal and noise.

Alexithymia and Metacognitive Ability

We predicted that alexithymia would be associated with metacognitive sensitivity in our emotion task, but that it would only be associated with metacognitive sensitivity in our perceptual task if metacognitive ability is shared across content domains. Using the Area under the Type 2 ROC (AUROC2), we compared participants' metacognitive sensitivity in the Dot

Task and RMET tasks (see Fleming & Lau, 2014; Galvin et al., 2003). The measures of metacognition used here could not be used on the Trust Game because we used a one-shot version of the game and did not collect confidence associated with particular trials. In contrast to our expectations, Spearman correlations between TAS-20 scores and AUROC2 were not significant for the RMET ($p = .31$, Figure 1C). Additionally, there was no relationship between TAS-20 scores and AUROC2 at any of the SNRs in the Dot Task (see Figure 2, row 3 for details). This suggests that, despite being less confident, individuals with high alexithymia were no less aware of their task performance than their peers in both the emotional and perceptual domains, refuting both the emotion-specific and general metacognitive deficit hypotheses we preregistered.

To more directly measure metacognitive ability, we also calculated the ratio of participants' meta- d' to d' scores as a measure of metacognitive efficiency (see Maniscalco & Lau, 2012). We did not expect metacognitive efficiency to have a different relationship to alexithymia than metacognitive sensitivity, i.e. we expected no relationship between TAS-20 scores and metacognitive efficiency on the Dot Task. However, if individuals with high alexithymia had performed very poorly on the Dot Task, metacognitive efficiency would have been a better measure of metacognitive performance than the AUROC2 measure we used. Spearman correlations revealed no correlations between TAS-20 scores metacognitive efficiency at any SNR of the dot task after using a Bonferroni correction ($\alpha = .0125$, all $p > .019$; see Supplementary Figure 9). Overall, these results are consistent with the observation that alexithymia showed no relationship to Dot Task performance or metacognitive sensitivity, and suggest that alexithymia has no relationship to metacognitive ability, even after controlling for task performance.

Relationships between Decision-Making Tasks

Performance across Tasks

In addition to our goal of understanding alexithymia's role in decision-making, we were interested in studying how decision-making was related across content domains. While all of these analyses were preregistered, we did not preregister any hypotheses regarding their outcomes. To begin this examination, we analyzed the relationship between participants' performances across tasks. A Wilcoxon signed-rank test revealed that total percent-correct was significantly higher for the RMET ($Mdn = 75$) than for the Dot Task ($Mdn = 71$) when tested across all SNRs ($p = .036$). When separated by SNR as an exploratory measure, Wilcoxon signed-rank tests revealed that only performance in the .05 SNR trials of the Dot Task was significantly lower than RMET performance ($Mdn = 53$, $p < 2.2e-16$), after using the Bonferroni adjustment. Dot Task performance exceeded that of RMET performance at the .65 SNR ($Mdn = 87$, $p = .028$), but it did not survive the Bonferroni adjustment ($\alpha = .01$). Total percent-correct, across SNRs, on the Dot Task was not correlated with total percent-correct on the RMET ($r = .0092$, $p = .76$). Exploratory Spearman correlations between percent-correct scores on the RMET and Dot Task were insignificant at all SNRs in the Dot Task ($p > .18$; see Supplementary Materials for details), indicating no relationship between performance across tasks. Thus, participants generally performed better on the RMET compared to the Dot Task and there was no correlation between the performances in both tasks. As noted earlier, performance in the Trust Game was calculated differently than the percent-correct scores used in the RMET and Dot Task. When comparing performance on the Trust Game to other tasks, we used the absolute difference between the actual and predicted number of tickets returned to the investor when the average

trustee received 15 tickets. It is worth noting that this measure may not be directly comparable to percent-correct scores, as it is a single-point of data rather than summary over a collection of responses. Participants' prediction accuracy in the Trust Game was not significantly correlated with total accuracy on the RMET ($r = -.13, p = .125$), but was negatively correlated with total accuracy on the Dot Task, when collapsed across SNRs ($r = -.20, p = .0253$). When broken down by SNR in an exploratory analysis, the correlation between Dot Task and Trust Game prediction accuracy remained negative for all SNRs, but consistently failed to reach significance ($\alpha = .0125$, all $p > .03$; see Supplementary Figure 2 for details). An exploration between investment and reciprocity in the Trust Game and RMET scores is reported in the Supplementary Materials. Overall, our results suggest that performance across content domains is generally dissociable, although accuracy scores in our perceptual and social task were negatively correlated.

Confidence across Dot Task, RMET, and Trust Game

Our study design also provided us with a distinctive opportunity to examine the relationship between confidence ratings across content domains. A Friedman test demonstrated that confidence ratings were significantly different across tasks ($\chi^2(2) = 80.8, p < 2.2e-16$), with post-hoc Mann-Whitney tests revealing that the confidence ratings were significantly lower for the Trust Game compared to both the RMET ($Z = -8.5, p = 2.2e-16$) and Dot Task ($Z = -6.2, p = 1.3e-10$), while the Dot Task and RMET did not differ significantly from one another ($Z = -0.15, p = .88$). Interestingly, participants' confidence ratings across tasks all had strong positive correlations with each other ($p < .01$, see Table 1). In particular, median confidence across the entire Dot Task was positively correlated with both median confidence on the RMET ($r = .53, p$

Table 1. Spearman correlations of confidence ratings across tasks.

	<i>Dot Task</i> <i>SNR =</i> <i>.05</i>	<i>Dot Task</i> <i>SNR =</i> <i>.25</i>	<i>Dot Task</i> <i>SNR =</i> <i>.45</i>	<i>Dot Task</i> <i>SNR =</i> <i>.65</i>	<i>Total Dot</i> <i>Task</i>	<i>RMET</i>	<i>Trust</i> <i>Game</i>
<i>Dot Task</i> <i>SNR = .05</i>		.81***	.64***	.57***	-	.43***	.32***
<i>Dot Task</i> <i>SNR = .25</i>			.90***	.83***	-	.50***	.35***
<i>Dot Task</i> <i>SNR = .45</i>				.94***	-	.50***	.33***
<i>Dot Task</i> <i>SNR = .65</i>					-	.47***	.25**
<i>Total Dot</i> <i>Task</i>						.51***	.34***
<i>RMET</i>							.39***
<i>Trust</i> <i>Game</i>							
<i>Computed correlations used spearman-method with listwise-deletion.</i>							

Note. $p < .0005$ ***, $p = .0057$ **, Bonferroni-adjusted $\alpha = .0024$. Bolded results represent pre-registered analyses.

= 1.7e-9) and prediction confidence on the Trust Game ($r = .34$, $p = 1.4\text{e-}4$). Likewise, median confidence on the RMET was positively correlated with prediction confidence in the Trust Game ($r = .39$, $p = 1.1\text{e-}5$). In order to take a more granular approach to the examination of the relationship between confidence ratings across tasks, we conducted exploratory analyses that broke the Dot Task down by its four SNR conditions. Breaking up the correlations by SNR allowed us observe that this positive correlation was not only significant, but relatively similar in strength at all levels of difficulty (see Table 1). Our data demonstrate that an individuals' confidence ratings may differ between tasks (e.g. by difficulty), but generally tend to be similar

across different content domains. In short, confidence ratings, in our study, acted like a general personality factor and were not content-specific.

Metacognitive Sensitivity across Tasks

The relationship between participants' metacognitive sensitivity, measured by the AUROC2, on the RMET and Dot Task was tested using separate Spearman correlations for each SNR in the Dot Task. None of these correlations indicated a significant relationship between metacognitive sensitivity on the RMET and Dot Task after correcting for multiple comparisons (all $p > .050$; see Figure 3). It is worth noting, however, that with the exception of the highest SNR level (.65), there was generally low variability in metacognitive sensitivity scores in the Dot Task. Overall, our results support a distinction between metacognitive sensitivity in the perceptual and emotional domains.

Figure 3. Spearman correlations between metacognitive sensitivity, measured by Area Under the Type-two ROC Curve (AUROC2), on the RMET and each SNR of the Dot Task. The SNR in the Dot Task increases from left to right, where graph A represents the .05 SNR condition and graph D represents the .65 SNR condition. All correlations failed to reach significance at the Bonferroni-adjusted alpha level ($\alpha = .0125$).

Effects of Gender and Age across Tasks and TAS-20 Scores

While not preregistered, we decided to conduct exploratory analyses using age and gender as variables to check whether these demographics had a stronger relationship with decision-making than alexithymia. Wilcoxon Rank-Sum tests revealed no effect of gender on

TAS-20 scores ($W = 1770$, $p = .92$) or on performance on the Dot Task ($W = 1700$, $p = .79$) or RMET ($W = 1772$, $p = .91$). However, in the Trust Game, a Wilcoxon Rank-Sum test revealed that the number of tickets invested was higher for male-identified participants ($Mdn = 4$) than for female-identified participants ($Mdn = 3$; $W = 1276.5$, $p = .0095$). There was no such relationship between gender and the number of tickets returned (all $p > .07$).

Age was significantly correlated with both TAS-20 scores (Spearman method; $r = .325$, $p = .00026$) and percent-correct on the Dot Task collapsed across SNRs (Pearson method; $r = -.27$, $p = .0028$). The negative correlation between age and percent-correct on the Dot Task holds for all SNRs greater than .05 (see Supplementary Figure 3). While there was no relationship between age and number of tickets invested in the trust game ($r = -.027$, $p = .76$), there was a positive correlation between age and mean return ratio ($r = .23$, $p = .008$). Age was not correlated with confidence at any level of the Dot Task (all $p > .60$), the RMET ($r = .041$, $p = .66$), or the Trust Game ($r = -.087$, $p = .35$). These results suggest that gender and age affect these decision-making paradigms differently, where age is primarily associated with performance in the Dot Task and reciprocity in the Trust Game, and gender with investment in the Trust Game.

Discussion

The present study sought to more precisely define the scope of alexithymia and its influence on decision-making by gathering data from perceptual, social, and emotional domains at the levels of performance, confidence, and metacognition. We found that, while alexithymia was not associated with performance or metacognitive sensitivity across content domains, it was negatively correlated with confidence in both the perceptual and emotional domains. This demonstrates an avenue through which alexithymia may affect one's experiences beyond

situations that require explicitly emotional tasks (e.g. communicating one's feelings, recognizing others' mood). Furthermore, by collecting data from different content domains, we were able to draw some conclusions regarding the extent to which decision-making across tasks may rely on similar cognitive mechanisms. While performance and metacognitive sensitivity were generally unrelated across domains, we found that confidence was positively correlated across all three domains, with a moderate to strong effect size, suggesting that confidence may be a character trait.

Alexithymia had no relationship with participants' performance or metacognitive ability.

Despite its association with poor social wellbeing and aversive personality traits in previous research, our results showed no relationship between alexithymia and social-economic decision-making. Although alexithymia was negatively correlated with trust in the Trust Game, this relationship failed to reach significance. Furthermore, there was no association between alexithymia and reciprocity in the Trust Game. Our results suggest that in one-shot interactions, individuals with high alexithymia do not act less altruistically or trust others less than other participants do. If alexithymia affects social-economic decision-making, its effect size may be small enough that our study did not have sufficient power to detect, or the effect may only manifest in more complex situations that require more social inference and risk assessment (e.g. a multi-round Trust Game).

Interestingly, our data collected from the RMET, a task that was designed to require significant social-emotional inference, failed to demonstrate a relationship between alexithymia and task performance (see Figure 1A). Alexithymia has been consistently associated with poorer emotional facial recognition in a wide variety of tasks (Grynberg et al., 2012) including the

RMET (Kara & Yılmaz, 2018; Oakley, Brewer, Bird, & Catmur, 2016; Redondo & Herrero-Fernández, 2018; Rødgaard, Jensen, & Matttron, 2019), although at least one study found no relationship between RMET and TAS-20 scores (Riem et al., 2018). It is unclear why our results were not consistent with the majority of studies that examine this relationship. One explanation is that alexithymic tendencies may stem from diverse causes. While some individuals with high alexithymia may have broad difficulties identifying emotion categories, others may only exhibit alexithymic tendencies because they have learned to avoid emotions as a coping mechanism (e.g. due to co-occurring mental health problems; Segerstrom & Smith, 2019). An over-arching weakness of conceptual emotion categories may worsen one's ability to identify others' emotions, but avoidance of stressful emotions is only likely to affect this ability insofar as it causes one to experience stressful emotions themselves. Different samples of alexithymia may have different proportions of people with similar underlying causes, and thus may produce different results in emotion recognition tasks. The results from our sample suggest that alexithymia is not associated with a broad inability to recognize emotional categories, at least when they are being expressed by other people.

The absence of a relationship between alexithymia and emotional facial recognition is made more intriguing by the negative correlation between alexithymia and confidence in the RMET (see Figure 1B), suggesting a discrepancy between self-perceptions of performance and true behavior. However, the absence of a relationship between alexithymia and metacognitive ability in the Dot Task or RMET suggests that alexithymia has no relationship to individuals' abilities to distinguish between correct and incorrect trials. Moreover, the absence of a correlation between alexithymia and decision-criteria or performance on the Dot Task suggests that alexithymia is not associated with an increased need for more evidence in order to

consistently categorize a stimulus correctly. Individuals with high alexithymia, thus, do not appear to make perceptual judgements any differently from other participants in the absence of differential reward/punishment outcomes for false positive and false negatives, despite being on average less confident about those decisions. It may be that alexithymia only influences decision criteria or metacognitive sensitivity in perceptual tasks where one type of error has steeper consequences than another. Regardless, it is worth noting that in the absence of these contingencies, alexithymia was not related to metacognitive sensitivity in either the emotional or perceptual domain, suggesting that it does not affect mechanisms of self-reflection broadly or directly.

Alexithymia was negatively correlated with confidence across certain tasks

While alexithymia was not related to performance in any of the three domains, it was negatively correlated with confidence in both the perceptual and emotional tasks. Alexithymia was not related to confidence in the Trust Game, but it is unclear whether this is indicative of a general lack of association with confidence in social decisions or whether the one-shot design of the current study was simply not robust enough to capture any existing relationship. Exploratory *post-hoc* analyses indicated that the Difficulty Identifying Feelings (DIF) subscale of the TAS-20 correlations was driving the negative correlations with confidence ratings in the Dot Task and RMET. Removing the DDF and EOT subscales both strengthened the observed relationships and revealed additional significant correlations at different SNRs in the perceptual task. We propose two possible explanations for these findings – the first requires us to examine the nature of confidence ratings and the second to examine the interpretation of the TAS-20.

Alexithymia may be associated with lower confidence because the experience of confidence includes emotional information that individuals with high levels of alexithymia cannot access. Emotions provide summaries about the value of situations and actions, which can motivate an actor to behave in a certain way (e.g. consistent with broader goals). Therefore, even in the presence of sensory information, being unable to develop or access feelings could reduce the amount of information available to a decision-maker, amplifying perceived uncertainty. In this way, emotional experience may be a crucial component in the calculation of uncertainty about one's performance. The negative correlation between confidence and alexithymia may be due to a failure in the shared mechanisms between emotional representations and confidence. In support of this, our results showed no relationship between alexithymia and metacognitive ability in either the emotional or perceptual decision-making task, suggesting that alexithymia is not associated with conceptual representations broadly, but with perceptions of certainty specifically. Under this framework, the negative correlation between confidence and alexithymia, or more specifically DIF, is actually quite intuitive: to the extent that confidence ratings rely on emotional mechanisms, poorer ability to identify feelings would reduce the overall available amount of information in making a confidence rating. Interestingly, this could be due to a reduction in emotional signal (e.g. lower emotional reactivity, inability to integrate interoceptive cues) or an increase in noise (e.g. multiple competing representations of emotion becoming overwhelming), a question which may warrant further exploration.

A strong competing explanation of the results hinges on how to best interpret scores on the TAS-20. The TAS-20 overall, especially the DIF subscale, has recently been subject to scrutiny regarding its validity as a measure of alexithymia. It has been suggested that the TAS-20 may be more accurately construed as a measure of psychological distress, a general index of a

variety of different unpleasant feeling states and mental health symptoms. In turn, this would explain the close relationship between the TAS-20 and the myriad mental health problems with which it is associated (Marchesi et al., 2016). In particular, a recent factor analysis by Preece et al. (2020) found that the DIF subscale of the TAS-20 cross-loaded onto a psychological distress factor whereas the other TAS-20 subscales and other alexithymia questionnaires loaded onto one alexithymia factor. Given that our results linking alexithymia and confidence ratings were driven by the DIF subscale, it is possible that psychological distress, rather than alexithymia *per se*, is associated with lower ratings of confidence.

Indeed, both alexithymia and psychological distress have been linked to low self-confidence (Yelsma, 1995; Liu et al., 2014). One study, using the French translation of the TAS-20, found that both depression and the combined DIF and DDF subscales of the TAS-20 demonstrated strong, negative correlations with self-reported self-confidence (Loas et al., 2000). Similarly, in a behavioral study of emotion recognition, people with higher self-reported depression tended to have lower confidence ratings (Fieker et al., 2016). This link between psychological distress and lower confidence has implications in applied settings too – medical practitioners with higher levels of psychological distress were less confident in their ability to perform clinical and practical tasks (Williams et al., 1997). Thus, one interpretation of our data is that the presence of high psychological distress, measured by the DIF subscale, implies low self-esteem which may cause participants to question their own reliability as observers and lead to lower confidence ratings. This would suggest a more top-down generation of confidence ratings, where one's current stress levels and/or general self-esteem determines their perceptions of certainty.

While this is an intuitively appealing interpretation, it contains a few weaknesses that warrant further examination. First, the creators of the TAS-20 have contested the accusations of low-validity and overlap with psychological distress, pointing out that the TAS-20 has sometimes shown no relationship to mental health symptoms and has loaded onto its own factor when analyzed in conjunction with the 21-Item Beck Depression Inventory (Bagby, Parker, & Taylor, 2020). Additionally, there is relatively little research that truly links psychological distress and confidence ratings in behavioral tasks, and the literature that does exist shows somewhat mixed findings. For example, in a study examining visual perception in depressed and non-depressed participants, researchers found no relationship between confidence ratings and depression (Herskovic, Kietzman, & Sutton, 1986).

Future research into the determinants and mechanisms of confidence ratings should consider the roles that psychological distress and alexithymia and attempt to disentangle them, if possible. Understanding how these constructs relate to confidence may provide some insight into what these confidence ratings mean, informing both our interpretation of past and future data and our understanding of how the brain generates, represents, and reduces uncertainty from the sensory signals it receives.

Confidence, but not metacognitive ability, was correlated across tasks

The convergence of confidence ratings across tasks provides behavioral evidence for an underlying general confidence factor that lacks domain-specificity. This interpretation is supported by previous findings identifying confidence as a potentially stable, trait-like factor in both perceptual (Navajas et al., 2017; Stankov & Crawford, 1996) and social decision-making (Catterson, Naumann, & John, 2015). Past research comparing confidence judgements across cognitive and perceptual tasks has also found evidence for a general confidence factor that

remains robust even after accounting for measures of personality or intelligence (Pallier et al., 2002). The present study corroborated these findings and provided a more robust exploration of the relationship between confidence ratings across tasks by examining three domains at once. Future research should examine the stability of the cross-domain correlations of confidence ratings within participants in an effort to elucidate whether this confidence factor is stable over time, like a personality trait. Additionally, it may be informative to explore which, if any, personality traits are associated with confidence ratings within and across tasks.

Though many studies use only confidence as a measure of metacognition in decision-making (in alexithymia, see Lorey et al., 2012; for a general review of the literature on confidence see Grimaldi, Lau, & Basso, 2015), our study distinguished between confidence and metacognitive sensitivity in the Dot Task and RMET. While confidence provides valuable information about how a participant perceives the validity of their observation (see Grimaldi et al., 2015), metacognitive sensitivity provides information about whether those perceptions align with reality. Interestingly, while confidence was closely related across tasks in our study, metacognitive sensitivity on the RMET and Dot Task showed no relationship. However, it is important to note that the low performance and greatly restricted variance in metacognitive sensitivity scores on the Dot Task, coupled with the higher variance and stronger correlation at the highest SNR suggest that this result may be a product of our task construction. Perhaps metacognitive sensitivity would have been more strongly correlated across tasks if our Dot Task had been easier or participants had been given more training on the task. Regardless, the results presented here suggest that while one's confidence may be attributable to some general personality factor, the ability to distinguish between correct and incorrect trials may be more content-specific.

The question of general versus specific metacognitive ability remains unresolved among researchers in metacognition. While there is substantial support for domain-specific metacognition (Fleming et al., 2014; Keleman, Frost, & Weaver, 2000; Morales, Lau, & Fleming, 2018; Valk et al., 2016), the definitions of both “metacognition” and “domain” vary widely, making it hard to draw any strong conclusions. Many of these studies separate content into perceptual versus conceptual or perceptual versus memory domains, but these categories have not been well-defined. For example, it is unclear whether social or emotional perception, such as in the RMET, should be best considered perceptual or conceptual especially when it involves decoding complex visual information (e.g. faces). Moreover, there is also evidence supporting the view that confidence is represented by shared processes across content domains (Kvidera & Koutstaal, 2008; Morales, Lau, & Fleming, 2018). While the absence of a correlation between metacognitive sensitivity in the Dot Task and RMET supports a distinction between emotional and non-emotional metacognitive ability, our study was not designed to rigorously test the nature of these content domains. Future research should seek to more clearly delineate the types of metacognitive domains, should they exist at all.

Limitations

There are several limitations to the present study that should be considered when approaching future work in this area. First, our university’s outreach program required that all studies at the State Fair take less than 30 minutes to complete. This informed and restricted many of our choices in study design. Given more time, it would be valuable to include additional questionnaire measures to examine which, if any, traits or symptoms predict performance, confidence, and metacognitive ability in these tasks. It would be particularly valuable to include

a measure of psychological distress in addition to a measure of alexithymia that has not shown the same overlap with psychological distress as the TAS-20, to help clarify the role these constructs play in decision-making.

Additionally, the testing environment at the State Fair was less than ideal for behavioral research. The testing facility was noisy and crowded and participants occasionally had to wait for people ahead of them to finish a study before starting. Moreover, while conducting the study at the State Fair provided access to a wider variety of participants than university studies, it was evident that many of the participants were less familiar with computers and had not participated in cognitive research before. As a result, performance in the computerized tasks, especially the Dot Task, may have suffered. On the other hand, our results provide insights regarding behavior in these tasks for “naïve” participants, which is particularly relevant in the context of the Dot Task (given that behavior in this task is often over-trained).

The use of SDT and the related AUROC2 measure in the present study offered us valuable insight by allowing us to separate confidence and metacognitive ability. However, the structure of the Trust Game prevented us from performing analyses on metacognitive sensitivity and the structure of the RMET violated the assumptions of SDT, preventing us from analyzing metacognitive efficiency (namely, it was a four-alternative forced choice task and not a 2AFC). Unfortunately, there are very few tasks for emotional and social perception that follow a SDT framework. Given that separating metacognitive ability, confidence, and performance can provide more information about different decision-making processes, it may be worth developing more tasks that follow the assumptions of SDT. Using tasks that can all be analyzed using an SDT framework could help increase the comprehensibility of comparisons across tasks.

Finally, it is worth noting that the use of the RMET as a measure of emotional facial expression recognition, while supported by the literature (Oakley et al., 2016), is not the intended purpose of the test. The RMET was originally designed to measure the ability to recognize mental states generally (Baron-Cohen et al., 2001), although Oakley et al. suggest that these mental states tend to carry emotional information. Furthermore, work by Nook et al. (2015) suggests that individuals with high alexithymia tend to struggle to identify emotions when faced with the challenge of labeling those emotions themselves, but perform more normally when emotion labels are provided. Therefore, a study using no pre-determined emotion labels may succeed in finding a significant difference in emotional task performance between low and high alexithymia participants, which may in turn have downstream consequences in comparing metacognitive sensitivity across alexithymia levels. Finally, it is important to note that despite the fact that alexithymia tends to be related to poorer emotion recognition in others, it is primarily a measure of whether one can access their own emotions. Future research may seek to examine the relationship between alexithymia and performance on a task that examines emotion generation instead.

Conclusions

In summary, participants' TAS-20 scores were associated with lower confidence beyond just the emotion recognition task, implying that alexithymia may be associated with lower general confidence in task performance (despite similar performance levels). These results shed light on the role of emotions in decision-making, suggesting that awareness of one's emotions may help to constrain subjective uncertainty in one's performance. Future research into the relationship between alexithymia and decision-making may provide valuable insight into the

mechanisms behind confidence judgements, providing a window into how the brain monitors task performance and develops conscious representations of uncertainty.

We also found that neither performance nor metacognitive sensitivity were correlated across tasks. However, confidence ratings were strongly correlated across tasks, suggesting that general confidence may be a personality trait. Our study was not primarily designed to examine these inter-task relationships, but we believe it is important that future research attempts to replicate these findings in an effort to continue the field's continued interest in the domain-specificity of subjective uncertainty and metacognitive sensitivity.

At a fundamental level, our results help elucidate the functional role of emotions, an important endeavor given that the very definition of emotion itself remains an unsettled issue in affective science (Gross & Barrett, 2011). They also have implications in the personal and clinical realms: given its relatively high prevalence and association with poorer mental and social health, alexithymia has strong influences on the quality of life of many people. Understanding how alexithymia may impact the way an individual experiences decision-making may therefore be useful information for both individuals with high alexithymia and mental health counselors, who already have trouble treating clients with alexithymia (Taylor, 1984). Altogether, we hope that these results also provide a greater appreciation for the role of emotions, and emotional awareness, in decision-making.

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