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ASSESSMENT OF THEORY OF MIND IN STROKE POPULATIONS

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An Appraisal of the Assessment Tools

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Summary of the MRP portfolio

Section A

A systematic review that aimed to explore the Theory of Mind (ToM) measures that have been utilised within the recent stroke literature and evaluate the degree to which they are appropriate for people that have had a stroke. Thirteen articles and 14 different ToM assessment tools were eligible for the review. The assessment tools and other aspects of the reviewed studies were critically appraised and used to inform the extent to which conclusions could be drawn from the stroke literature. It was identified that most tasks were appropriate. However, caution was raised with regards to making solid conclusions based on the existing literature due to several factors. The review concluded with recommendations for prospective studies.

Section B

A quantitative study that aimed to examine the use and utility of the Cambridge Mindreading Face-Voice Battery (CAM; Golan, Baron-Cohen, & Hill, 2006) within stroke populations. Group comparisons of CAM performance between 22 stroke survivors and 20 age- and education-matched healthy control participants showed no significant differences. An exploratory cluster analysis revealed different ToM patterns within the stroke sample. These findings were discussed in the context of existing neuropsychological and neuroscience literature and theory.

Section C

Appendices of supporting material.

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MAJOR RESEARCH PROJECT

Section A: Literature Review

Theory of Mind in Stroke Populations: An Appraisal of the Assessment Tools

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Abstract

Theory of Mind (ToM) is the ability to infer mental states to self and others. Some studies have shown that people with acquired brain injury generally exhibit deficits in ToM, although there are exceptions within the literature. These discrepancies may be partly attributable to the diverse range of tools used to quantify ToM abilities within these clinical groups. The present review aimed to explore the ToM measures that have been employed within stroke populations and evaluate the degree to which they are appropriate for people that have had a stroke. In consideration of these factors, the review included a discussion regarding the extent to which conclusions – with respect to the ToM impairment or preservation – could be drawn from the stroke literature. A systematic exploration of the literature revealed that besides the Reading the Mind in the Eyes task, other ToM measures utilised within the literature were social-cognitive in nature, most of which were verbally-demanding. Although social-cognitive ToM tasks are heavily dependent on general cognition, the review identified that most tasks included appropriate control stimuli and/or items. However, few studies demonstrated the psychometric properties of these tools, which impeded potential clinical implications. The review concluded with recommendations for prospective studies.

Keywords: Theory of Mind, Stroke, Acquired Brain Injury, Neuropsychological Assessment

Introduction

What is Theory of Mind?

As defined in Premack and Woodruff's (1978) influential article on chimpanzee behaviour, theory of mind (ToM) refers to one's ability to attribute mental states to self and others. It involves the skill to deduce the mental state of others from perceptual cues (e.g., speech content, facial expression) as well as a separate social-cognitive component that is responsible for making inferences regarding the mental states (thoughts, feelings, etc.) of other people (Tager-Flusberg & Sullivan, 2000). Despite major theoretical advances in the ToM literature over the last 30 years (Apperly, 2012; Slaughter, 2015), its multidimensional nature (Hughes & Leekam, 2004) has continued to prove challenging to measure experimentally, particularly beyond childhood. Although this complication may be partly attributable to the range of cognitive processes known to contribute to ToM (Frith & Frith, 2003; Sabbagh, 2004), the systematic differences between the methods by which it is assessed is also likely to be partly responsible (Mahy, Moses, & Pfeifer, 2014).

Beyond being a theoretical construct, the ability to decode (i.e., social-perceptual ToM) and make mental state inferences (i.e., social-cognitive ToM) enables one to predict the impact of their actions on other people, making ToM core to human interaction and behaviour (Sperber & Wilson, 1995). Although the literature has predominately focused on exploring ToM abilities during childhood (Carpendale & Lewis, 2006; Doherty, 2009), recent studies have demonstrated its relevance across the lifespan. It has been linked to better social functioning in adults, including interpersonal communication (Bora, Eryavuz, Kayahan, Sungu, & Veznedaroglu, 2006), participation in activities of daily living (Purcell, Phillips, & Gruber, 2013) and engagement in pleasurable activities (Wang et al., 2015).

Theory of Mind in People with Acquired Brain Injury (Stroke)

Following scientific breakthrough within child developmental psychology research during the late 20th century, ToM has been extensively studied across a range of clinical populations, including adults with acquired brain injury. Given that people with right hemisphere damage (RHD) from stroke were known to present with social and communication difficulties (Brownell, Griffin, Winner, Friedman, & Happe, 2000), early ToM studies focused on this population; most of which demonstrated that people with RHD exhibited deficits across both verbal and non-verbal ToM tasks (Griffin et al., 2006; Happe, Brownell, & Winner, 1999; Siegal, Carrington, & Radel, 1996; Winner, Brownell, Happe, Blum, & Pincus, 1998). However, Surian and Siegal (2001) revealed that working memory deficits may account for observed ToM impairments in some cases, highlighting the importance of considering other cognitive abilities when assessing ToM in populations with acquired brain injury.

Despite the emphasis on RHD, some lesion studies involving a diverse range of neurological populations (e.g., traumatic brain injury) have observed ToM impairments in people with more defined lesions, including the right prefrontal regions (Channon et al., 2010; Rowe, Bullock, Polkey, & Morris, 2001; Shamay-Tsoory, Berger, & Aharon-Peretz, 2003) and the temporoparietal junction (Apperly, Samson, Chiavarino, & Humphreys, 2004). A series of ToM experiments conducted by researchers at the University of Birmingham implicated the right inferior frontal gyrus in the inhibition of one's self-perspective (Samson, Houthuys, & Humphreys, 2015;

Schurz & Tholen, 2016), whereas the left temporoparietal junction has been linked to perspective taking (i.e., facilitating one's attention to the environmental information that is necessary to infer the mental state of another person) (Apperly, Samson, Chiavariono, Bickerton, & Humphreys, 2007; Samson, Apperly, & Humphreys, 2007); both of which are – to some extent – requirements across a range of ToM tasks (Aboulafia-Brakha, Christe, Martory, & Annoni, 2011). These neuropsychological findings are in line with recent neuroimaging evidence implicating the fronto-parietal-temporal network in ToM (Carrington & Bailey, 2009), however the picture is complicated by the few studies that have found preserved ToM abilities in stroke survivors with RHD (Tompkins, Scharp, Fassbinder, Meigh, & Armstrong, 2008) and prefrontal lesions (Bird, Castelli, Malik, Frith, & Husain, 2004). Arguably, the evidence base taken as a whole is likely to be a reflection of the diverse range of processes involved in ToM (Apperly & Butterfill, 2009), as well as the variety of tools used to measure it within acquired brain injury (viz., stroke) and healthy control populations.

Types of Stroke

Stroke is a type of brain dysfunction attributable to a disturbance in cerebral blood flow. It can occur either through the blockage of blood vessels supplying parts of the brain (viz., ischaemia) or bleeding from these blood vessels (viz., haemorrhage). Stroke is one of the leading causes of morbidity and premature mortality (Global Burden of Disease Study, 2015; Krishnamurthi et al., 2013), thus emphasising the importance of developing innovative ways to reduce its individual and societal impact. As well as being a major cause of physical disability, stroke typically results in a compromise of some form of cognitive functioning, including processes that underpin social abilities, otherwise known as social cognition (Hommel et al., 2009; Renjen, Gauba, & Chaudhari, 2015). Improving the way in which social cognition (e.g., ToM) is assessed in these populations will have positive clinical implications by enabling accurate detection of such deficits.

How is Theory of Mind Measured?

Since Wimmer and Perner (1983) developed the False-belief paradigm, which requires participants to infer the false belief of a protagonist within a narrative, a wide range of ToM assessment tools have been constructed within the field of developmental psychology (Carpendale & Lewis, 2006; Doherty, 2009). A lot of these tasks have been adapted for use within specific adult populations, including those that have experienced stroke (Apperly, Humphreys, & Samson, 2009).

Social-cognitive ToM tasks are the most widely used ToM tools in populations with acquired brain injury (Martin-Rodriguez & Leon-Carrion, 2010). These tasks can be presented within a first-order format, whereby participants are instructed to infer the knowledge, belief, desire, or intention of a protagonist within a visually and/or verbally presented scenario (e.g., During a race between Alexa and Isaiah, Alexa tripped over a rock. What is going through Alexa's mind?). There are also second-order social-cognitive ToM tasks, which tap into one's capacity to infer a protagonist's beliefs regarding a deuteragonist's mental state (e.g., where does Alexa think Hanne will first look for her lunch?). These social-cognitive ToM tasks are typically presented in the form of the previously described False-belief paradigm (Apperly, 2011), which offers researchers the advantage of being able to clearly distinguish between a person's true belief representation (i.e., what they know) and their ability to conceptualise the inaccurate belief of protagonists.

An alternative method to assessing social-cognitive ToM involves simply asking a person to infer the mental state of a protagonist based on the contents of a narrative presented to them (e.g., Daniel told Matthew that he would be with him in 5 minutes, when in fact he was 30 minutes away. Why did Daniel say this?). A similar approach to assessing ToM features in the widely-used Faux Pas task (Stone, Baron-Cohen, & Knight, 1998). With regards to the Faux Pas task, participants are required to detect whether a protagonist within the presented narrative has said something inappropriate, which is typically followed by questions tapping into their ability to infer the mental states of the protagonists (speaker or receiver). A recent meta-analysis revealed that populations with acquired brain injury showed moderate deficits in first- and second-order social-cognitive ToM tasks, whereas severe deficits were observed in their Faux Pas performance (Martin-Rodriguez & Leon-Carrion, 2010), emphasising the multi-faceted nature of the ToM construct, or at the very least, the differences between the tools used to quantify it.

Since its development, the Reading the Mind in the Eyes task (RMET; Baron-Cohen, Jolliffe, Mortimore, Robertson, 1997) – a social-perceptual measure of ToM based on one’s ability to decode the mental state of protagonists based on pictures of their eye region – has occasionally been employed within populations with acquired brain injury (Havet-Thomassin, Allain, Etcharry-Bouyx, & Le Gall, 2006; Milders, Fuchs, & Crawford, 2003).

Considering the importance of developing neuropsychological assessment tools that can more accurately detect social impairment within stroke populations (Channon & Crawford, 2010), alongside the fact that there are a myriad of ToM measures that have been adapted for use within neurological populations, and more specifically, stroke survivors, it is surprising that there has yet to be a qualitative review of studies exploring ToM abilities in stroke survivors, with a specific focus on the tools used to derive the findings. The present review will aim to contribute to the literature by filling this gap and where available, there will be reference to the psychometric properties of the ToM measures used.

Aims of the Review

The present review will appraise ToM measures and associated studies within the existing stroke literature.

The literature review will address two sub-questions, namely:

a) What measures have been used to assess ToM in stroke populations and to what extent are they appropriate for use within this clinical group?
b) What conclusions can be drawn from the literature?

Due to the variance across the literature with regards to stroke participant population and design, the use of a critical appraisal tool would offer minimal comparison between eligible studies, thus it was decided that they would not be employed within the present review.

Methodology

Three electronic databases (PsycINFO, Web of Science and MEDLINE) were searched from their earliest entries to December 2016 using keywords relevant to stroke and ToM, which were as follows: stroke OR “cerebrovascular disorder*” OR “cerebrovascular accident” OR haemorrhagic OR hemorrhagic and “theory of mind” OR “social cogniti*” OR empathy OR “emotion* recogni*” OR mentali*. As Martin-

Rodriguez and Leon-Carrion (2010) conducted a meta-analysis of studies investigating ToM deficits in populations with acquired brain injury up to June 2008, it was decided that the present review will exclude articles published prior to this month.

For the purpose of the review, ToM will be defined as the capacity to form direct representations of other people's mental state and/or to use these representations to understand, predict and judge utterances and behaviour (Brownell & Martino, 1998). This definition of ToM rules out basic visual perspective-taking tasks, which have distinct cognitive features to belief reasoning tasks, such as automaticity (Back & Apperly, 2010; Samson, Apperly, Braithwaite, Andrews, & Bodley-Scott, 2010). In addition to the social-cognitive component of ToM that involves inferring the thoughts, beliefs, and intentions of others, the present review will also include tasks tapping into the decoding perceptual-based capacities, known as social-perceptual ToM (Tager-Flusberg & Sullivan, 2000). Social-perceptual ToM tasks that require participants to attribute complex affective mental states that imply cognitive attribution (e.g., surprise) will be included. However, measures that solely assess participants' ability to recognise basic or situational-based emotions from facial stimuli, including happiness, sadness, anger, fear and disgust, will be excluded. Basic emotion recognition is thought to involve a different process to inferring an affective mental state (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), thus forming the basis for this omission.

Measures that exclusively assess the capacity of detecting irony or a social transgression (faux pas), moral judgment, processing humour, understanding metaphors or simple problem-solving tasks that do not explicitly force participants to make direct inferences regarding mental states, were also not included within the present review. Considering the high density of contextual information provided within such measures, successful performance might rely on an intact social script or the utilisation of superficial problem-solving strategies, rather than one's ability to attribute accurate mental states to others (Apperly, 2011). As it was intended for clinical implications of ToM assessment to be drawn from the review, studies that did not directly compare the performance of stroke and healthy control samples on eligible ToM measures were excluded.

Abstracts and full articles were screened using inclusion/exclusion criteria (see Figure 1 for a flow chart):

- Article must be published in English.
- Paper must describe empirical and peer-reviewed research.
- At least one explicit ToM measure must be administered within the study (only tasks that meet inclusion criteria will be discussed).
- There must be a stroke survivor sample or participant whose performance on an eligible ToM task is compared against healthy controls.
- It must not involve participants under 18 years old.
- Articles must be published on or after June 2008.

The reference lists of all eligible articles and relevant reviews were manually inspected for the purpose of identifying additional eligible papers. If it was suspected that a study and associated ToM measure would be eligible for the present review, but the article lacked the details to include it (e.g., there was a control group but the comparison with the stroke sample was not made explicit within the article), there was an attempt made to contact the author/s directly for further information. ToM measures used in the included studies were recorded and where possible, their original references were sought for further information.

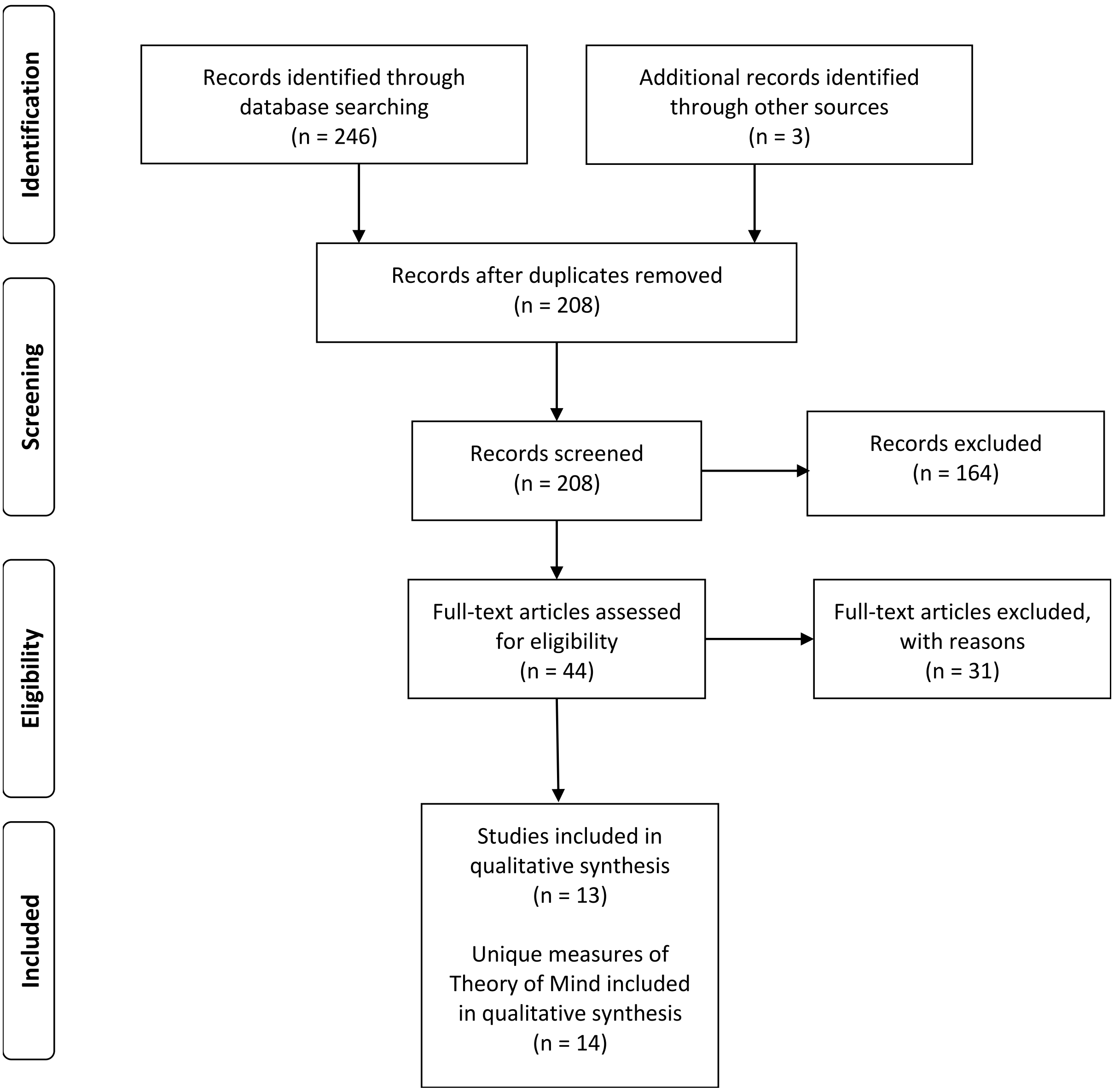

Figure 1. A flowchart for the search strategy used

Results

See Tables 1, 2, and 3 for a list of the identified ToM measures, design characteristics of the eligible studies, and brief summaries of the associated studies, respectively.

Table 1

Properties of the Reviewed Theory of Mind Measures

			Presentation			Questions	
Participants with Right Hemisphere Damage							
Study Author	Year	Measure Used	Stories	Pictures	Video	ToM	Control
Balaban et al.	2016	aTOMia battery	False belief: 2 Second-order false-belief: 1 Knowledge gaps: 2 Instruction: 4 Faux pas: 2 Surprise: 2 Empathy: 2	Cartoon: 2	-	False belief: 2 Second-order false-belief: 2 Knowledge gaps: 4 Instruction: 8 Faux pas: 4 Surprise: 4 Empathy: 6 Cartoon: 2	False belief: 2 Second-order false-belief: 4 Knowledge gaps: 2 Instruction: 0 Faux pas: 2 Surprise: 2 Empathy: 2 Cartoon: 2
Besharati et al.	2016	ToM stories	20 (4 controls)	-	-	16	4

Champagne-Lavau & Joannette	2009	ToM task	20	-	-	20	40
Leigh et al.	2013	Affective Empathy Task	1	-	4	18	NR
Weed et al. (see Abell et al., 2000)	2010	Animations task	-		10 (2 practice)	8	2
Participants with Right and Left Hemisphere Damage							
Martory et al.	2015	GeSoCS	Social cognition: 5	Mind in the Eyes: 10 ToM cartoons: 5	-	Social cognition: 5 Mind in the eyes: 10 ToM cartoons: 5	Social cognition: NR ToM cartoons: 1
Yeh & Tsai	2014	FPT (Chinese)	10	-	-	20	-
Yeh & Tsai	2014	Picture task	-	10	-	10	-
Participants with Discrete Lesions							
Couto et al. (see Baron-Cohen et al., 2001)	2013	RMET	-	36	-	36	-
Gerschcovich et al. (see Baron-	2011	RMET	-	36	-	36	-

Cohen et al., 2001)							
Kemp et al. (see Baron-Cohen et al., 2001)	2013	RMET (French)	-	36	-	36	-
Kemp et al. (see Ehrle et al., 2011)	2013	FBT	19 (11 first order, 8 second order)	-	-	19 (11 first order, 8 second order)	38 (22 first order, 16 second order)
Kemp et al.	2013	FPT (French)	20 (10 faux pas)	-	-	30	40 (20 faux pas)
Sedeno et al. (see Baron-Cohen et al., 2001)	2016	RMET	-	36	-	36	-
Wilkos et al. (see Baron-Cohen et al., 2001)	2015	RMET	-	36	-	36	-
Xi et al. (see Zhu et al., 2007)	2013	FPT (Chinese)	10	-	-	20	10
Xi et al. (see Wang et al., 2008)	2013	RMET (Chinese)	-	34	-	34	34

Note. NR = not reported; N/A = not applicable; ToM = Theory of Mind; FPT = Faux Pas task; FBT = False-belief task; RMET = Reading the Mind in the Eyes task; Geneva Social Cognition Scale.

Table 2

Design Characteristics of the Reviewed Studies

			Stroke sample					Control sample		
Authors	Year	Country	Size (n)	Onset	Lesion site	Aphasia excluded	Psychiatric History excluded	Size (n)	Age-matched	Education-matched
Participants with Right Hemisphere Damage										
Balaban et al.	2016	Israel	22[a]	3 – 60 months	RHD	Y	NR	14	NR	Y
Besharati et al.	2016	UK	30	Mdn = 8.5	RHD	Y	Y	15	Y	Y
Champagne-Lavau & Joannette	2009	Canada	15	1 – 4 months	RHD	NR	Y	15	Y	Y
Leigh et al.	2013	USA	27	“acute”	RHD	N	N	24	Y	Y
Weed et al.	2010	Denmark	11	1 – 7 months	RHD	N	N	10	NR	Y
Participants with Right and Left Hemisphere Damage										

Martory et al.	2015	Switzerland	31	10-21 days	LHD, RHD and bilateral	Y	Y	52	NR	NR
Yeh & Tsai	2014	China	34	NR	RHD & LHD	Y	Y	40	Y	Y
					Participants with Discrete Lesions					
Couto et al.	2013	Argentina	2	GG: 18 months NF: 12 months	GG: focal insular cortex lesion NF: subcortical stroke affecting connections of the insular cortex with frontotemporal areas	N/A	N/A	10	GG: Y NF: Y	GG: Y NF: N
Gerschcovich et al.	2011	Argentina	1	3 months	Bilateral cerebellar infarction	N/A	N/A	21	Y	Y
Kemp et al.	2013	France	1	46 months	Left caudate nucleus	N/A	N/A	12	Y	Y
Sedeno et al.	2016	Argentina	4	≥ 6 months	Frontoinsular	NR	NR	12	Y	N
Wilkos et al.	2015	Poland	8	3 weeks	Unilateral thalamic infarction	NR	Y	11	NR	NR

Xi et al.	2013	China	19	M = 36.42 days SD = 8.91	Unilateral temporal lobe cerebral infarction	NR	Y	20	Y	Y

Note. n= number; Y = yes; N = no; NR = not reported; N/A = not applicable; RHD = right hemispheric damage; LHD = left hemispheric damage; GG & NF = stroke patients within Couto et al.’s (2013) study; Mdn = Median; M = Mean; SD = Standard deviation.
[a]Balaban et al.’s (2016) study also included three participants with acquired brain injury that was not due to stroke.

Table 3

Main Findings of the Reviewed Studies

Authors	Year	Measure	Findings
Participants with Right Hemisphere Damage			
Balaban et al.	2016	aTOMia battery	14 out of 22 stroke patients had significantly lower total scores on the battery than the education-matched control group. The group analysis (which also included three patients with right hemispheric damage from other neurological pathologies) revealed that the acquired brain injury sample performed poorer than the healthy control sample on five out of eight ToM categories: knowledge gaps, instruction, faux pas, empathy (first and second order) and the mental state cartoon tasks, whereas there were no differences observed in false belief (first and second-order) and surprise subtasks.
Besharati et al.	2016	Theory of Mind stories	They found that a stroke patient sub-group (right hemispheric damage: presenting with anosognosia for hemiplegia) performed poorer than the two control groups (healthy and stroke patients with right hemispheric damage and contralateral hemiplegia, but without anosognosia). Further analysis revealed that the stroke patients with anosognosia for hemiplegia exhibited a deficit in third-person perspective (difference between their performance on first-person and third-person ToM tasks) in comparison to the hemiplegic stroke patients without anosognosia and healthy control sample.
Champagne-Lavau & Joannette	2009	Theory of mind task	Stroke survivors performed poorer than the healthy control sample across the first- and second-order theory of mind items, however this pattern was also observed within the inferential processing and comprehension questions and measures of pragmatic understanding used within the study. A hierarchical cluster analysis revealed a co-occurrence of theory of mind and pragmatic impairments and/or executive dysfunction in different stroke sub-groups.

Leigh et al.	2013	Affective Empathy Task	14 out of 27 stroke patients met criteria for impaired affective theory of mind determined from the performance of the healthy control group. Nine of the 14 patients found to have a theory of mind impairment had lesions to one or more brain regions implicated in the affective theory of mind network: right prefrontal cortex, orbitofrontal gyrus, anterior cingulate cortex, anterior insula, temporal pole and amygdala. A very strong association between the presence of a lesion in one or more of these regions of interest and impairments on the ToM task was identified, whilst the only significant independent associations were between compromised affective ToM and an infarct in the temporal pole or in the anterior insula.
Weed et al.	2010	Animations task (Abell et al., 2000)	No significant difference in the extent to which the stroke survivors and an education-matched control group explicitly referenced specific mental states when describing animations. However, a second coding procedure which accounted for implicit ToM revealed poorer performance in the stroke sample[a].
Participants with Right and Left Hemisphere Damage			
Martory et al.	2015	GeSoCS	Stroke patients with right, left and bilateral hemispheric cerebrovascular accident performed poorer than the healthy control sample across all ToM measures (social cognition, Mind in the Eyes and cartoons) as well as the items assessing general inferential abilities and executive functioning. Post-hoc analyses revealed that stroke patients with right cerebrovascular accident performed poorer on the cartoons and Mind in the Eyes subtasks as well as one executive function measure. On the other hand, the left cerebrovascular accident group performed significantly poorer than controls in the social cognition and cartoon sub-tasks as well as the general inference task and one measure of executive functioning. Patients with bilateral cerebrovascular accident were significantly impaired across all three theory of mind tasks, the general inference task and the two executive function measures.
Yeh & Tsai	2009	Chinese version of the Faux Pas task	Stroke patients with right or left hemispheric damage performed poorer than the control group on both cognitive and affective theory of mind items. This difference retained significance even when general cognition was accounted for within the analysis.

Yeh & Tsai	2009	Picture task	Stroke patients with right or left hemispheric damage performed poorer than the healthy control group on both cognitive and affective theory of mind items. A post-hoc analysis indicated that the stroke sample with right hemispheric damage performed significantly poorer than the stroke group with left hemispheric damage on the cognitive items, but not on the affective component. The differences identified remained significant even when general cognition was accounted for within the analysis.
Participants with Discrete Lesions			
Kemp et al.	2013	French version of the Faux-Pas Test	Stroke patient with left caudate nucleus damage, MVG performed poorer than the control group on the ToM items excluding one, which assessed second-order belief reasoning.
Kemp et al.	2013	First- and Second-Order False-Beliefs Task (Ehrle et al., 2011)	Stroke patient with left caudate nucleus damage, MVG did not significantly differ from age- and education-level matched controls in both first- and second-order false beliefs task performance.
Kemp et al.	2013	French version of the Reading the Mind in the Eyes test	Stroke patient with left caudate nucleus damage, scored significantly less than the controls.
Couto et al.	2013	Reading the Mind in the Eyes test (Baron-Cohen et al., 2001)	No significant differences between G.G. (focal insular cortex lesion following stroke) and N.F. (subcortical stroke affecting connections of the insular cortex with frontotemporal areas) and the healthy control sample.
Gerschcovich et al.	2011	Reading the Mind in the Eyes test (Baron-Cohen et al., 2001)	Stroke survivor with bilateral cerebellar infarction performed below 7 standard deviations of the mean healthy control sample's performance.

Sedeno et al.	2016	Reading the Mind in the Eyes test (Baron-Cohen et al., 2001)	A Mann-Whitney U test using data provided by the authors identified that there were no significant differences between the performance of the stroke patients with frontoinsular lesions and the healthy control sample (see Appendix A).
Wilkos et al.	2015	Reading the Mind in the Eyes test (Baron-Cohen et al., 2001)	Stroke patients with unilateral thalamic infarction performed poorer than the control group.
Xi et al.	2013	Chinese version of the Reading the Mind in the Eyes test (Wang et al., 2008)	Stroke patients with temporal lobe cerebral infarction performed poorer than the control group on the theory of mind task. Additionally, there were no significant differences between the performance of the stroke and healthy control group on the gender discrimination (control) task.
Xi et al.	2013	Recognition of Faux Pas task (Zhu et al., 2007)	Despite no group performance differences on the story comprehension control item or faux pas detection, stroke patients with temporal lobe infarction performed poorer than the healthy control group on the questions that assessed cognitive theory of mind

Note. [a]The additional coding procedure was not discussed within the review as it did not meet the inclusion criteria.

Literature Review

For the purposes of structuring the present review and enabling meaningful between-study comparisons, investigations will be organised with regards to the stroke population within which ToM was explored, including those that have included stroke survivors broadly described as having right hemisphere damage (RHD), studies that involved one or more participants with clearly defined lesions (e.g., cerebellar damage) and, less precise investigations that comprised those with right and left hemisphere damage (LHD).

Right Hemisphere Damage

In line with the historical literature (see Introduction), a significant proportion of studies (n = 5) within the present review solely included stroke survivors with the broad label of RHD.

What ToM tasks were used?

All the ToM tasks used in these investigations were social-cognitive in nature, four of which were predominantly verbally-based (Balaban, Friedmann, & Ziv, 2016; Besharati et al., 2016; Champagne-Lavau and Joanette, 2009; Leigh et al., 2013). However, Leigh et al.'s ToM task involved a partly non-verbal (video with audio) component and Balaban et al.'s ToM battery consisted of one non-verbal subtask (Cartoons), which required participants to infer the mental state of protagonists depicted within an animated picture. The remaining study conducted by Weed, McGregor, Nielsen, Roepstorff, and Frith (2010) administered a non-verbal ToM task, which comprised eight animations selected from the clips used within Abell, Happe and Frith’s (2000) study, to 11 participants with RHD and 10 education-matched healthy controls. The chosen dynamic animations consisted of two triangles, half of which were ‘Theory of Mind’ animations that showed one triangle seemingly reacting to the mental state of the other triangle, whereas this was not the case for the remaining animations, within which the triangles did not interact with one another (‘Random’ animations). After each randomised trial, participants indicated whether they felt there was a story in the animation, and were subsequently instructed to describe it. The comments generated by the latter question were blindly rated – on the extent to which a (mental state) intention had been inferred – by one of the researchers and two independent raters, all of whom followed Abell et al.’s coding framework, resulting in a moderate Cohen’s kappa coefficient of 0.488.

With regards to the verbal ToM tasks, both Champagne-Lavau and Joanette’s (2009) and Besharati et al.’s (2016) study assessed participants on tasks that were presented in the form of a narrative involving two protagonists and first- and second-order questions. However, Champagne-Lavau and Joanette’s ToM task was administered to 15 people with RHD and 15 age- and education-matched controls in the form of a false-belief paradigm, whereas Besharati et al.’s investigation included 20 stories – four of which were controls – that tapped into ToM through self-referential (e.g., how do you feel about your friend breaking their leg?) and the typical, third-person perspective questions. Furthermore, unlike the False-belief task in Champagne-Lavau and Joanette’s study which solely explored one’s ability to infer beliefs, Besharati et al.’s ToM task consisted of an equal division of items that tapped into cognitive (e.g., Claire is trying not to hurt Eddie’s feelings) and affective-based (e.g., Jessica feels relieved that she did not kill her friend’s cat) mental inferences, thus incorporating these two dissociable aspects of social-cognitive ToM (Shamay-Tsoory, Tomer, Berger, Goldsher, & Aharon-Peretz, 2005; Kalbe et al., 2010).

On the other hand, Leigh et al. (2013) developed a social-cognitive ToM task, known as the Affective Empathy Task, which exclusively tapped into participants' ability to infer affective mental state. It consisted of sixteen questions that assessed participants' ability to attribute affective mental states to protagonists in four videos – depicting a social scenario – and two questions linked to a verbally-presented narrative. Alongside administering the task to patients with acute ischaemic right hemisphere stroke within 24 hours of their hospital admission, a neurologically-intact sample of 24 patients that had experienced a transient ischaemic attack were recruited as the healthy control sample.

Lastly, Balaban et al. (2016) devised a tool consisting of eight ToM tasks, which was referred to as the aTOMia battery. It comprised first-order false-belief, second-order false-belief, knowledge gaps[1], instruction[1], Faux Pas, surprise[1], empathy[1], and cartoon[2] tasks. Five out of the eight ToM categories involved stimuli (e.g., story) from an established ToM measure and a second story, which was specifically created by the authors to match the first scenario with respect to narrative length and complexity. Although this battery offers a broad assessment of ToM, similar to the other RHD studies, it relies on social-cognitive ToM, which has been found to be distinct from the social-perceptual component (Ahmed & Miller, 2011). Furthermore, as highlighted by Apperly (2011), poor performance on social-cognitive tasks in people with acquired brain injury may be attributable to a range of factors, thus the challenge for researchers

[1] Verbal theory of mind task that required participants to infer the belief and/or intention of a protagonist within a presented narrative.
[2] Non-verbal theory of mind task that required participants to infer the intention of an animated protagonist within a picture.

is to pinpoint the aetiology and/or account for extraneous variables that may influence performance on these tasks, including working memory (Stone et al., 1998) and language comprehension (Surian & Siegal, 2001).

The ToM tasks used in the RHD studies were somewhat responsive to this potent limitation of social-cognitive ToM tasks when applied to neurological population through the inclusion of control items. For the narrative-based measures (Balaban et al., 2016; Besharati et al., 2016; Champagne-Lavau & Joanette, 2009; Leigh et al., 2013), this involved a set of questions that assessed participants' general comprehension and memory, however Champagne-Lavau and Joanette and Besharati et al. also assessed general inferential abilities, which if impaired, would undoubtedly affect domain-specific ToM abilities (Apperly, Samson, & Humphreys, 2005). While Champagne-Lavau and Joanette tapped into this domain-general ability by including non-mental state inference questions alongside the false-belief and comprehension questions, Besharati et al.'s task comprised four control narratives – that required (non-mental) general inferences to reach an accurate conclusion. On the other hand, owing to its non-verbal nature, Weed et al. (2010) instead ensured participants understood the task instructions via two practice trials. The inclusion of non-ToM (Random) animations enabled the researchers to disentangle the domain-general demands of the task – considering the ToM and Random conditions were similar – and ability of participants to infer mental states within the ToM condition. This non-verbal task, alongside the Affective Empathy Task (Leigh et al.) involved dynamic stimuli (although arguably, inferring the mental state of shapes may have little relevance to interpersonal challenges in real-world situations), whilst the other tasks required participants to engage in artificial narratives. Considering the abundant presence of information normally available within the natural environment (e.g., motion, facial expressions), the other reviewed social-cognitive tasks may lack ecological validity (Turkstra, 2008).

Sampling Comparisons.

With regards to samples, two of these studies (Besharati et al., 2016; Leigh et al., 2013) involved stroke patients at the acute stage of their recovery, whereas the stroke survivors in the remaining studies were at least one month post-onset, although this ranged up to 60 months in Balaban et al.'s (2016) investigation. It is plausible that ToM abilities – as is the case with other aspects of cognition – will improve with time following stroke (Hochstenbach, den Otter, & Mulder, 2003), which might imply that comparisons between studies involving stroke patients in the acute stage and stroke survivors further along their rehabilitation may be misleading, unless clearly highlighted.

Besides Weed et al.'s (2010) study, the remaining investigations explicitly matched the stroke and healthy control participants by age, although the paper highlighted that the median age for both groups was 65 years. This is an important design feature considering the well documented effect of older age on social-cognitive ToM task performance (Henry, Phillips, Ruffman, & Bailey, 2013). Education was another factor that was matched in all studies except one (Besharati et al., 2016). There is some evidence to suggest education (Oishi et al., 2014; Yildirim et al., 2011) and premorbid intelligence (Charlton, Barrick, Markus, & Morris, 2009) influences performance on social-cognitive ToM tasks, emphasising the importance of accounting for it within sampling procedures. There was less attention paid to the exclusion criteria, with three studies not explicitly excluding stroke and healthy control participants with a psychiatric history (Balaban et al., 2016; Leigh et al., 2013; Weed et al., 2010), which is known to influence ToM capacity (Mitchell & Young, 2016; Sprong, Schothorst, Vos, Hox, & van Engeland, 2007). Also, considering most of the tasks within the RHD studies relied on verbal processing, aphasia is another noteworthy factor in apparent ToM performance. Most of the studies did not exclude stroke survivors with aphasia (Champagne-Lavau & Joanette, 2009; Leigh et al., 2013; Weed et al., 2010), however this is less problematic for the latter study which utilised a non-verbal ToM task. Furthermore, the inclusion of control items within the verbal ToM tasks may have identified participants that were unable to successfully complete ToM items due to impaired verbal comprehension, which minimises the potential bias from this domain-general ability.

What were the findings?

As all the reviewed RHD investigations were cross-sectional studies, between-group comparisons were generally conducted, except in Leigh et al.'s (2013) study which identified a cut-off score of a 30% error rate using the performance of the control group. Using this criterion, they found 14 out of 27 (51.9%) stroke patients were impaired on the ToM task. Balaban et al. (2016) conducted a between-group analysis alongside an individual analysis using Crawford and Howell's (1998) approach to single-case comparisons, which revealed 14 out of 22 stroke survivors (63.6%) had significantly lower total scores on the aTOMia battery than the education-matched control group. It is plausible that the higher proportion identified within Balaban et al.'s study in comparison to Leigh et al. is attributable to the extensive nature of the aTOMia battery, which increases its likelihood to detect ToM impairment in one or more of its subtasks. In line with this position, the group analysis revealed that the acquired brain injury sample performed poorer than the healthy control sample on five out of eight ToM categories: knowledge gaps, instruction, faux pas, empathy and the mental state cartoon tasks, whereas there were no significant between-group differences observed in first- and second-order false belief and surprise subtasks.

Balaban et al.'s (2016) findings of non-significant between-group differences in the false-belief tasks contrasts with Champagne-Lavau and Joanette's (2009) and Besharati et al.'s (2016) study, which demonstrated that stroke survivors performed poorer than the healthy control sample across first- and second-order ToM items. However, in the case of Champagne-Lavau and Joanette's investigation, a hierarchical cluster analysis conducted within the study revealed a co-occurrence of pragmatic impairments and/or executive dysfunction in stroke survivors with ToM deficits, suggesting that the observed ToM impairments may have been accounted for by these domain-general abilities. This is consistent with Weed et al.'s[3] (2010) investigation, whose ToM task had limited, if any pragmatic demands due to its nonverbal nature, which revealed no significant differences in the extent to which the stroke and education-matched control groups explicitly referenced specific mental states when describing the animations within the ToM condition. However, as there were no measures of pragmatic understanding within Balaban et al.'s investigation, this hypothetical explanation – that suggests apparent ToM deficits in RHD may be a function of impairment in pragmatic understanding – cannot be confirmed. Nevertheless, this position is supported by previous studies in RHD samples (Siegal et al., 1996; Surian & Siegal, 2001).

[3] Weed et al. (2010) conducted a second coding procedure in response to the non-significant between-group comparisons, however the task in this form (implicit ToM) did not meet inclusion within the present review.

As Besharati et al. (2016) subdivided their stroke sample into those with and without anosognosia for hemiplegia, further analysis revealed that stroke survivors with anosognosia had a specific impairment in self-referential ToM, suggesting that the ability to infer mental states to self and others may be underpinned by separate mechanisms. As the other RHD studies exclusively assessed ToM via the third-person, between-study comparisons with regards to this factor could not be made, although there is some evidence from a relatively recent neuroimaging study in support of this ToM dissociation (Otsuka, Osaka, Yaoi, & Osaka, 2011).

Left and Right Hemisphere Damage

Two studies involved participants that had experienced a left or right cerebrovascular accident (Martory et al., 2015; Yeh & Tsai, 2014), although the former also included those with bilateral stroke.

What ToM tasks were used?

While Martory et al. (2015) developed a novel social cognition battery, known as the Geneva Social Cognition Scale (GeSoCS), Yeh and Tsai (2014) used an adapted version of the widely used social-cognitive ToM measure, the Faux Pas task and a 10-picture item social-cognitive ToM measure, five of which assessed cognitive reasoning while the remaining tapped into affective ToM. Unlike the original Faux Pas task (Stone et al., 1998), Yeh and Tsai's version consisted of 10 rather than 20 stories, all of which consisted of a scenario whereby a protagonist made a social transgression (faux pas). It included associated ToM items that tapped into first-order cognitive (e.g., "what is the person thinking?") and affective reasoning (e.g., "what is the person feeling?").

Similarly, the nonverbal picture task – which was used in a previous study (Yeh et al., 2010) – tapped into the dissociable cognitive and affective ToM component, although examined this through asking participants to infer the intention of a protagonist within animated pictures presented to them.

On the other hand, the GeSoCS consisted of six separate tasks, 3 of which assessed ToM. The first task (social cognition) required participants to make inferences based on four presented stories from established verbal social-cognitive ToM measures, including the Faux Pas task (Stone et al., 1998). The second ToM measure comprised ten photographs from the revised RMET (Baron-Cohen et al., 2001), which tapped into social-perceptual ToM, whereas the third ToM task consisted of five picture stories that required participants to infer first- and second-order false beliefs and one control story without ToM-specific inferential processing demands. While Martory et al. (2015) included some second-order questions, Yeh and Tsai's (2014) Faux Pas and Picture tasks lacked second-order items, which is likely to reduce their capacity to identify stroke survivors with mild to moderate ToM deficits (Martin-Rodriquez & Leon-Carrion, 2010). However, to the testament of the adapted tasks used in Yeh and Tsai's study, the authors highlighted strong reliability properties in both the Faux Pas (Cronbach's alpha of 0.91 and re-test reliability of 0.89) and Picture tasks (Cronbach's alpha of 0.93 and re-test reliability of 0.90).

There was an apparent omission of control items within both ToM tasks administered within Yeh and Tsai's (2014) study. Particularly given that Faux Pas narratives consist of complex social situations that may require more than ToM capacities (Martin-Rodriguez & Leon-Carrion, 2010), items to ensure story comprehension are paramount. The lack of this feature limits the extent to which domain-general abilities (e.g., working memory) can be ruled out as an explanation for possible between-group differences. In contrast, the GeSoCS consisted of control items to assess for linguistic comprehension. Also, alongside the ToM tasks, the GeSoCS consisted of three subtests that tapped into participants' ability to make general inferences and executive functioning. Considering the strong association between these domain-general abilities and ToM (Aboulafia-Brakha et al., 2011; Champagne-Lavau & Joanette, 2009), the inclusion of these items within the GeSoCS equips it with the valuable property of being able to rule them out as explanations for ToM deficits that may be observed within stroke populations.

Sampling Comparisons.

Yeh and Tsai (2014) matched 34 stroke and 40 healthy control participants according to age and education, whereas there was a clear age difference between the 31 stroke survivors and 52 healthy controls in Martory et al.'s (2015) study. However, as there were no explicit group comparisons between age or education in Martory et al.'s investigation, this cannot be confirmed. Given that Martory et al. aimed to develop a clinical tool, unlike Yeh and Tsai, they did not exclude stroke patients with aphasia. It is plausible that this may have confounded their findings, particularly with respect to the LHD sample, some of whom had aphasia according to the authors. Although, both studies excluded people with psychiatric history, minimising the source of ToM-specific bias from inclusion of people with severe and enduring mental health problems. As the two studies recruited people who had a stroke from acute wards, it is likely that the stroke samples only included people with acute stroke (although this was not made explicit within Yeh and Tsai's article), thus offering better scope for between-study comparisons than in the RHD literature which varied considerably with regards to post-onset duration.

What were the findings?

Yeh and Tsai (2014) found stroke survivors – irrespective of hemisphere affected – performed poorer than control group on both cognitive and affective ToM items of the Faux Pas and Picture task. The differences retained significance even when general cognition was accounted for within the analysis. Similarly, Martory et al. (2015) revealed stroke survivors performed less accurately than healthy controls across all ToM measures (social cognition, adapted RMET and cartoons), although they also performed poorer on the subtasks that assessed general inferential abilities and executive functioning. Post-hoc analyses revealed that stroke patients with RHD performed poorer on the Cartoons subtest and RMET as well as one executive function measure (i.e., temporal rules), whereas the LHD sample performed significantly poorer than controls in the Social Cognition and Cartoons subtasks as well as the general inference task and one measure of executive functioning (i.e., absurd stories). Those with bilateral cerebrovascular accident were significantly impaired across all three theory of mind tasks, the general inference task and both aforestated executive function measures. It is plausible that the observed ToM deficits across the stroke samples may have been attributable to the domain-general deficits shown using the GeSoCS (e.g., executive dysfunction), however this was not explored within the study.

Taken together, these studies suggest that – as well as stroke survivors with RHD – those with lesions in the left hemisphere also perform poorer on ToM tasks. This is consistent with neuroimaging studies that have shown left hemisphere activation in healthy adults while they complete social-cognitive ToM tasks (Fletcher et al., 1995). However, more recent evidence has implicated the left temporoparietal junction as a structure that underpins the domain-general ability of perspective-taking (rather than ToM), which plays a significant role in ToM task performance (Perner et al., 2006). Again, this emphasises Apperly's (2011) argument that highlights the presence of a variety of possible explanations for observed social-cognitive ToM deficits in people with acquired brain injury.

Discrete Lesions

Six studies explored the ToM capacities of stoke survivors with better defined lesions than the previously reviewed studies, including those located in the temporal lobes (Xi et al., 2013), cerebellum (Gerschcovich, Cerquetti, Tenca, & Leiguarda, 2011), right frontoinsular cortex and right putamen, claustraum and external capsule (Couto et al., 2013), thalamus (Wilkos, Brown, Slawinska, & Kucharska, 2015) and left caudate nucleus (Kemp et al., 2013). Half of these investigation employed a case-controls design (Couto et al.; Gerschcovich et al.; Kemp et al.), which was appropriate considering that they aimed to test specific hypotheses regarding brain-behaviour relationships and it is likely investigators did not have access to many people with clearly defined lesions in the brain regions under investigation due to population rarity. In contrast to the other case-control studies, Couto et al. involved two stroke survivors, one (G.G.) who had an ischaemic insular cortex damage and the other who experienced a right subcortical haemorrhage involving the right putamen, claustrum and the external capsule (N.F.).

What ToM tasks were used?

Each reviewed discrete lesion study involved the administration of the widely-used social-perceptual ToM task, RMET (Baron-Cohen et al., 2001), although two investigations included additional social-cognitive ToM tasks (Kemp et al., 2013; Xi et al., 2013). Xi et al. administered the Faux Pas task, whereas Kemp et al. employed a False-belief task alongside the Faux Pas task. These two aforestated studies were conducted in countries whereby English was not the native language and as such, the tasks were translated. The French version of the Faux Pas task administered within Kemp et al.'s study – similar to the original Faux Pas task (Stone et al., 1998) – consisted of twenty short stories, half of which were control stories that did not contain a faux pas. On the other hand, the previously published Chinese-translated Faux Pas task (Zhu et al., 2007) used within Xi et al.'s (2013) study adapted the task such that it did not consist of non-faux pas stories. Kemp et al. also retained ToM questions from the classic task, which tapped first- and second-order cognitive attributions and affective reasoning, whereas Xi et al. omitted affective ToM questions. Although there is a significant evidence base demonstrating the excellent psychometric properties of the Faux Pas task in healthy and clinical populations (Soderstrand & Almkvist, 2012; Zalla, Sav, Stopin, Ahade, & Leboyer, 2009; Zhu et al., 2007), it is plausible that the alterations in Xi et al.'s investigation may have compromised its validity.

Kemp et al. (2013) also administered a False-belief task (Ehrle, Henry, Pesa, & Bakchine, 2011), consisting of nineteen stories. Within this study, an investigator orally presented the false-belief stories to participants and subsequently asked three questions assessing first and second-order cognitive ToM, story comprehension and information recall. Although story recall is an important construct to assess within the context of a false-belief task, which places significant demands on memory (Callejas, Shulman, & Corbetta, 2011; Mutter, Alcorn, & Welsh, 2006), the omission of a general inferential ability question would suggest that the measure lacks the property to distinguish between specific ToM impairments and domain-general inferential deficits in stroke populations. As the original article for the False-belief task (Ehrle et al., 2011) used in the study was written in French, further details regarding the measure were not accessible.

Two of the six studies that involved the administration of the RMET were conducted by the same research group based in the Laboratory of Experimental Psychology & Neuroscience, Institute of Cognitive Neurology, Argentina. The earlier study (Couto et al., 2013) described two female stroke patients, G.G. and N.F. (see above) who completed the RMET amongst other social cognition measures. The more recent investigation from the research group (Sedeno et al., 2016) was primarily concerned with assessing the social-executive behaviour profiles of patients with behavioural variant frontotemporal dementia, however also included 10 patients with frontoinsular lesions from stroke (four of which were selected to complete the RMET) and 12 healthy controls. Another Argentinian study (Gerschcovich et al., 2011) presented the results of the cognitive assessment (including RMET) of a 52-year old male patient who experienced a bilateral cerebellar infarction and compared this with 21 age- and education-matched controls. In Poland, Wilkos et al. (2015) conducted a pilot study that compared the performance of eight acute stroke patients with unilateral thalamic lesions with 11 healthy control participants on a range of social cognition measures, including the RMET.

The remaining two (previously discussed) studies used translated versions of the RMET. Kemp et al. (2013) translated the task to French, whereas Xi et al. (2013)

used a Chinese-translated version of the RMET (Wang, Wang, Chen, Zhu, & Wang, 2008). In contrast to the original measure (Baron-Cohen et al., 2001), Xi et al.'s version consisted of 34 still images of the eye region of human faces and adapted the stimuli to exclusively consist of photographs of Asian people, thus increasing its applicability to the study's Chinese sample. As was the case for the original study (Baron-Cohen et al.), participants in Xi et al.'s investigation were also instructed to judge the gender of the photographed individuals, which enabled the distinction between general visual deficits and specific social-perceptual ToM impairments. In contrast, the other discrete lesion studies did not include this aspect of the original RMET task, resulting in the presence of this possible extraneous variable, for which the chance of bias is exacerbated in stroke populations due to the high prevalence of visual impairment (Sand et al., 2013).

Sampling Comparisons.

Three studies demonstrated that the stroke and healthy controls were equivalent with regards to age and education (Gerschcovich et al., 2011; Kemp et al., 2013; Xi et al., 2013), whilst additional information requested from Sedeno et al. (2016) revealed no significant between-group age or general cognition differences (see Appendix A). Similarly, the stroke and healthy controls within Xi et al.'s study were equivalent with respect to general cognition. In Couto et al.'s study, G.G. was matched with the control group with respect to age and education, however the second patient, N.F. was less formally educated than the controls. The authors attempted to minimise this potential threat to internal validity by conducting further statistical analyses whilst controlling for education level. On the other hand, there were clear age differences between the stroke and healthy controls within Wilkos et al.'s (2015) study. Due to the lack of group matching within some studies, it is plausible that observed differences may be attributable to demographic variation, rather than the specific brain lesions.

What were the findings?

Firstly, Kemp et al. (2013) found that the male stroke survivor (MVG) with a left caudate nucleus lesion performed poorer than healthy controls on faux pas detection and ToM items, including affective and cognitive questions, whereas he performed just as well on the control items, suggesting MVG's performance could not be attributed to the domain-general abilities of verbal comprehension and memory. Similarly, it was revealed that the stroke survivors with temporal lobe cerebral infarction in Xi et al. (2013) performed poorer than the healthy controls on the cognitive ToM items within the Faux Pas task, however no significant between-group differences were revealed with respect to both the story comprehension control items and faux pas detection.

With regards to RMET observations, both studies from the Laboratory of Experimental Psychology & Neuroscience (Couto et al., 2013; Sedeno et al., 2016) found non-significant differences between the stroke (that affected the insular cortex or connections between this region and frontotemporal areas) and healthy control samples (see Appendix A for Mann-Whitney U test completed using data provided by Sedeno et al.). On the other hand, the remaining studies involving stroke survivors with clearly defined lesions showed that they performed poorer than healthy controls on the RMET (Gerschcovich et al., 2011; Kemp et al., 2013;Wilkos et al., 2015; Xi et al., 2013), with the latter also showing no significant differences on the associated gender discrimination task, thus ruling out visual deficits as an explanation for poor social-perceptual ToM performance. Considering these investigations involved stroke survivors with different lesions, besides the two studies from the Laboratory of Experimental Psychology & Neuroscience, limited between-group comparisons can be made, however the observation of poor performance across these heterogeneous groups may be indicative of the various ways in which ToM may be compromised following stroke (i.e., domain-general processes). Nevertheless, there is a need for cross-sectional studies to further explore these apparent brain-behaviour links, as it is plausible that the findings from the case-control studies are confounded by sampling biases inherent within this design.

Discussion

What measures have been used to assess ToM in stroke populations and to what extent are they appropriate for use within this clinical group?

A range of assessment tools were identified within the present review, ranging from those that evaluate the capacity to attribute either an affective or cognitive mental state to a protagonist, multi-componential measures that tapped into both cognitive and affective ToM and lastly, batteries that comprised separate ToM subtests. Most tasks were social-cognitive in nature, although the single-case control studies and a few cross-sectional investigations assessed social-perceptual ToM using the well-established RMET. In general, the reviewed tasks included appropriate items that assessed ToM abilities as well as control items that provided examiners with the tools to distinguish between specific ToM impairments and domain-general deficits that some people within stroke populations may present with, including difficulties with general inferences.

Some of the tasks identified within the literature were adaptations of established ToM tasks, such as the Faux Pas task (Stone et al., 1989), for which there are known psychometric properties in adults. Although, considering these tasks were sometimes manipulated within studies (e.g., altering the stimuli), it is plausible that this may have implications for their validity and reliability. Generally, the psychometric properties of the ToM measures were not explored within the reviewed studies, despite the tendency to employ novel tasks, suggesting that methodological robustness has not been properly considered within the literature. Furthermore, the absence of prior validation studies involving people who have experienced stroke limits the applicability of the reviewed ToM tasks in stroke populations, especially considering the prevalence of deficits in domain-general abilities that may affect performance on ToM tasks, but not necessarily equate to an inability to infer mental states (Apperly, 2011). However, the GeSoCS (Martory et al., 2015) made some steps towards addressing this concern through incorporating executive function and general inference subtests, thus enhancing its status as a standalone ToM measure.

Most of the reviewed measures were verbally-demanding in nature (e.g., false-belief tasks), which may have been appropriate within the studies as they predominantly excluded stroke survivors with aphasia. However, considering the high prevalence of aphasia following stroke (Engelter et al., 2006), such verbal tasks may not provide a suitable way of assessing ToM within this population in clinical practice. The few, relatively novel, non-verbal measures revealed within the literature review, including the animations task (Weed et al., 2010), Picture task (Yeh & Tsai, 2014) as well as the established RMET might be more appropriate for assessing the ToM abilities of people with expressive and/or receptive language difficulties following stroke. Although, considering only one reviewed study included the gender recognition task associated with the RMET, there is the possibility that deficits identified by this social-perceptual task – in this form – may be attributable to visual impairment rather than compromised ToM. Unlike the other measures of ToM reviewed, the Affective Empathy Task (Leigh et al., 2013) involved dynamic and realistic video clip stimuli, which may be more reflective of social situations in real-life than static photographs (e.g., RMET) or artificial social-cognitive measures, thus enhancing its ecological validity.

The revelation of novel social cognition batteries (Balaban et al., 2016; Martory et al., 2015) consisting of tasks that assess social-cognitive, and in the case of the GeSoCS, also social-perceptual ToM across verbal and visual modalities is promising.

Given that ToM is a multi-componential construct (Martin-Rodriguez & Leon-Carrion, 2010), such an approach to assessing it within stroke populations is likely to be advantageous in research and clinical practice.

What conclusions can be drawn from the literature?

Taken together, these studies have involved heterogeneous stroke samples, although a large proportion of the cross-sectional investigations solely recruited those with RHD. Given that recent neuroimaging research suggests the involvement of more clearly defined brain regions within the fronto-parietal-temporal network (Carrington & Bailey, 2009), the rationale for this continued interest in the right hemisphere is unclear. However, there were also studies that explored ToM abilities in stroke survivors with clearly defined lesions, which are better placed to make brain-behaviour conclusions than broad RHD and LHD investigations.

Although not a criticism of any individual investigation, alongside the diverse range of measures used to tap ToM, the heterogeneous nature (e.g., different lesions, onset) of the stroke samples across the different studies restricts the extent to which meaningful comparisons can be made within the literature. In addition to the design flaws (e.g., poor group matching) evident within some studies, these between-study sample differences may account for the variable findings identified within the literature. Nevertheless, it is clear that stroke sometimes affects ToM performance, however, as Apperly (2011) argued, the challenge is pinpointing the explanation for poor performance across heterogeneous populations with acquired brain injury, including stroke.

Clinical implications

Although some of the reviewed studies indicated ToM deficits in stroke populations, as a result of the myriad of within-and between-study limitations, any conclusions made must be tentative at this point. Nevertheless, the continued development of sensitive measures of ToM within the literature will benefit clinicians tracking social cognition outcomes of stroke survivors engaged in neurorehabilitation (Channon & Crawford, 2010). However, in order to establish the use of these tools within clinical practice, more clarity – than is offered within the existing literature base – is required with respect to the psychometric properties of these measures.

In preparation of the potential translation of ToM assessment tools into clinical practice, it is imperative that ToM measures incorporating tasks that account for confounding domain-general abilities are developed and experimentally validated. The thorough assessment that can be provided by ToM tools with such properties will support clinicians in their formulation of the presenting core deficits and therefore, will have implications for the rehabilitation of people who experience stroke. For example, with the technology to diagnose specific ToM impairments, clinicians may be able to recommended more targeted ToM interventions (e.g., Lundgren & Brownell, 2010), which might be otherwise ineffective if the impairment is within domain-general cognitive abilities that are simply impinging on ToM task performance. The GeSoCS (Martory et al., 2015) enables the assessment of both social-cognitive and perceptual ToM across verbal and visual modalities within one clinical session, making it a good candidate for the eventual translation into rehabilitation practice. The utilisation of such tools which enable clinicians to tap into the multi-dimensional ToM profile of an individual with stroke may also have implications with regards to informing a strengths-based approach to ToM abilities and tailoring rehabilitation practices accordingly.

Directions for Future Research

Prior to any possible research to clinical translation, there is a clear need for quality improvement within the literature concerned with ToM abilities in stroke populations, to firstly, reduce sources of bias and increase understanding into the processes underlying possible ToM deficits. For this to be achieved, it is suggested that future studies

- match stroke and healthy control samples according to age and education at the very least. Consideration of extraneous variables (e.g., cognition) will also enhance the quality of subsequent investigations.

- report relevant psychometric properties for novel measures. However, it may be more advantageous for the literature to focus on developing existing ToM tasks by addressing the limitations highlighted within the review (e.g., omission of control items tapping into general inferential capacity), rather than the administration of unvalidated tasks. This theme of heterogeneity within the literature with regards to the ToM construct and how it is measured within stroke populations limits the extent to which comparisons and conclusions can be made, thus establishing gold standard tasks will be ideal.

- utilise ToM measures with clear verisimilitude (e.g., stimuli that consists of dynamic video or voice clips) that tap different components of ToM (e.g., verbal vs. visual modality, affective vs. cognitive), such as the Cambridge Mindreading Face-Voice Battery (CAM; Golan, Baron-Cohen, & Hill, 2006). This will ensure that findings generated within subsequent investigations are reflective real-world interpersonal situations that require ToM and move beyond the reductionist unitary perspective on the construct.

- explore the domain-general cognitive processes that might be contributing to ToM task performance in stroke populations (e.g., to what extent are ToM deficits in stroke populations attributable to executive dysfunction?). This may offer some insight into the contrasting findings within the stroke literature.

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MAJOR RESEARCH PROJECT

Section B: Empirical Research

Assessment of Theory of Mind in Stroke Survivors: Exploration of a Social-Perceptual Measure with Ecological Validity

Word Count: 8000 (plus 271 additional words)

For submission to Neuropsychologia

Salomons Centre for Applied Psychology
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Abstract

Over the last twenty years there have been several investigations exploring theory of mind (ToM) abilities within populations with acquired brain injury, including stroke survivors. Most neuropsychology studies involving people with acquired brain injury have assessed the cognitively-demanding, social-cognitive component of ToM, whereas the literature concerned with exploring social-perceptual ToM is limited by its reliance on measures that are not representative of ToM processes within real-world situations. The current study aimed to examine the use and utility of an ecologically-valid (verisimilitudinous) social-perceptual ToM task within stroke survivors, known as the Cambridge Mindreading Face-Voice Battery (CAM; Golan, Baron-Cohen, & Hill, 2006). Group comparisons of CAM performance between 22 stroke survivors and 20 age- and education-matched healthy control participants showed no significant differences. In addition, the CAM was unable to accurately distinguish between the groups. An exploratory cluster analysis revealed differential patterns of ToM impairment and preservation within the sample of stroke survivors. These findings suggest, studies that have attempted to tap social-perceptual ToM through artificial tasks and/or static stimuli may be overestimating the deficits observed within stroke samples, and tentatively points towards functional fractionation of social-perceptual ToM abilities dependent on modality. Some recommendations for future research combining neuropsychology and neuroimaging methodology are discussed.

Keywords: Theory of Mind, Ecological Validity, Stroke, Acquired Brain Injury; Neuropsychological Assessment

Introduction

'Setting the Scene'

Theory of Mind (ToM) refers to one's capacity to attribute mental states to self and other people and subsequently use these generated representations to evaluate, explain and anticipate consequential actions (e.g., Ollie is trying to cheer Sarah up because she is upset about coming fourth place in the bowling competition) (Brownell, Griffin, Winner, Friedman, & Happe, 2000). Tager-Flusberg and Sullivan (2000) argued that there are two components within ToM, namely, social-cognitive and social-perceptual abilities. They proposed that the social-cognitive aspect of ToM fits with traditional definitions of ToM as a representational system, whereas the social-perceptual component is involved in the on-line interpretation of readily accessible verbal (e.g., speech content, tone) and non-verbal information (e.g., facial expression, body language, actions).

Social-Cognitive Theory of Mind

Since the application of the ToM concept from chimpanzees (Premack & Woodruff, 1978) to human infants and children (Carpendale & Lewis, 2006), it has predominantly been evaluated using social-cognitive tasks, particularly the False-belief paradigm (Baron-Cohen, Leslie, & Frith, 1985; Happe, 1994; Perner & Wimmer, 1988; Wimmer & Weichbold, 1994). False-belief tasks tap into a person's ability to accurately conceptualise the incorrect belief state of a protagonist. For example, in the first-order Unexpected Transfer task (Wimmer & Perner, 1983), participants are presented with a narrative within which a protagonist leaves an item in a specific location and while they are absent, the item in question is displaced from its original location by a deuteragonist. Following this scenario, participants are asked where the protagonist will first look for the object. In order to successfully complete the task, the participant must consider the fact that the protagonist is unaware that the item has been moved in their absence, thus accurately judge that the protagonist will initially search the wrong (original) location due to their inaccurate belief that the object is still where they had left it. Typically developing children from the age of 4 years are able to successfully perform child-friendly versions of the first-order False-belief task (Wellman, Cross, & Watson, 2001), however the paradigm can be made more challenging through evaluating a person's ToM capacity via second-order False-belief tasks, which taps into one's ability to represent the beliefs that a protagonist holds about a deuteragonist's false belief (e.g., Antonia believes that Ophelia thinks she is going to miss the school bus today).

Although researchers tend to opt for false-belief tasks due to its advantage in being able to tease out a participant's own true belief (e.g., that the object has been moved from its original location) and their capacity to represent beliefs (e.g., that the protagonist will search for the object where they left it), there are other widely used social-cognitive ToM tasks, for example the Faux Pas (Baron-Cohen, O'Riordan, Jones, Stone, & Plaisted, 1999; Stone, Baron-Cohen, & Knight, 1998), Strange Stories (Happe, 1994; Happe, Brownell, & Winner, 1999) and Cartoons task (Corcoran, Cahill, & Frith, 1997; Happe et al., 1999; Sarfati, Hardy-Bayle, Besche,& Widlocher, 1997). For the Faux Pas task, participants are verbally presented with a narrative that involves a protagonist making a tactless remark towards a deuteragonist. They are initially required to detect the occurrence of the social transgression (faux pas), and if successful, their understanding of the faux pas is further explored by questions that tap into participants' ability to appreciate the mental state of the speaking protagonist and/or receiving deuteragonist (e.g., why shouldn't they have said it?). Similarly, the Strange Stories task involves the presentation of verbal stories, however in this case, the narratives were not limited to social situations involving a faux pas, for example it typically includes stories that involves the protagonist joking, lying or being sarcastic. Participants completing the Strange Stories task are initially required to judge whether what the protagonist said was true and they are subsequently asked to infer the intention of the protagonist (e.g., Jadon said it to trick his mother into giving him another snack). In contrast to the social-cognitive ToM tasks widely used in adult populations (Martin-Rodriguez & Leon-Carrion, 2010), the Cartoons task presents the narratives visually, either in the form of comic strips or animated drawings. In its traditional configuration, this ToM measure requires participants to demonstrate an understanding of a social situation that is dependent on an appreciation of a protagonist's and/or deuteragonist's mental state (e.g., the fisherman is not aware that there is a shark behind him, so he thinks the other man is afraid of the crab attached to his fishing rod).

Despite the typical inclusion of control items within these social-cognitive ToM measures (questions that evaluate whether a participant has adequately comprehended and/or retained key parts of a presented narrative, stimuli that requires participants to make non-mental state/general inferences, etc.), there remain potential drawbacks from assessing ToM using these tasks. Indeed, Apperly (2011) highlighted that a range of incidental performance demands were inherent within false-belief tasks, including verbal comprehension, attention, working memory and inhibition of self-perspective (true) belief. He argued that control items and/or stimuli within the traditional False-belief paradigm may not always sufficiently account for these extraneous cognitive demands. This is consistent with findings from experimental research involving adults with acquired brain injury, which revealed that poor performance on False-belief tasks were – in some cases – attributable to executive impairment (Samson, Apperly, Kathirgamanathan, & Humphreys, 2005) or difficulties in domain-general perspective-taking (Apperly, Samson, Chiavarino, Bickerton, & Humphreys, 2007; Apperly, Samson, Chiavarino, & Humphreys, 2004; Samson, Apperly, Chiavarino, & Humphreys, 2004) rather than deficits specific to social-cognitive ToM.

Similarly, the Faux Pas (Baron-Cohen et al., 1999) and Strange Stories (Happe, 1994) task, require participants to extract explicit information conveyed within the spoken and/or written narratives in order to accurately infer the mental state of a protagonist. This prerequisite places significant demands on complex verbal processing and executive functions (Ahmed & Miller, 2011). They also argued that the incidental demands inherent within these tasks were likely tapping into similar constructs to established executive function measures, such as the Delis-Kaplan Executive Function System (Delis, Kaplan, & Kramer, 2001). According to Muller et al. (2010), these verbal tasks also make substantial demands on pragmatic abilities, which may further detract from their purity as measures of social-cognitive ToM. Furthermore, faux pas detection has been linked to empathy, rather than being exclusive to the cognitive capacity to attribute mental states (Bird, Castelli, Malik, Frith, & Husain, 2004; Shamay-Tsoory, Tomer, Berger, & Aharon-Peretz, 2003), raising further questions of Faux Pas task's purity. Although the Cartoons task is more promising – as a social-cognitive ToM measure – with respect to its relative independence from verbal processing and working memory incidental demands (Corcoran et al., 1997), it has been found to have very high congruency with measures of shifting, verbal fluency, inhibition and working memory, suggestive of substantial executive involvement (Aboulafia-Brakha, Christe, Martory, & Annoni, 2011).

Apperly (2011) argued, that given the substantial demands that false-belief tasks (and as discussed, other social-cognitive ToM tasks) made on general cognitive abilities, it was not surprising that poor performance is often observed in people with acquired brain injury, including those with lesions confined to the right hemisphere (Griffin et al., 2006; Happe et al., 1999; Martin & McDonald, 2006; Siegal, Carrington, & Radel 1996; Surian & Siegal, 2001), frontal lobes (Rowe, Bullock, Polkey, & Morris, 2001; Stone et al., 1998; Stuss, Gallup, & Alexander, 2001), amygdala (Stone, Baron-Cohen, Calder, Keane, & Young, 2003) and the left temporoparietal junction (Apperly et al., 2004). Although neuropsychological research within this area of social cognition has predominately focused on attempting to localise the brain regions responsible for ToM capacity through exploring the performance of patients with acquired brain injury on social-cognitive ToM tasks (Martin-Rodriguez & Leon-Carrion, 2010), the primary challenge at hand is to distinguish the many possible reasons for poor performance in these tasks (Apperly, 2011). This includes deficits within the domain-general areas of executive functioning (Channon & Crawford, 2000), working memory (Stone et al., 1998), and language comprehension (Surian & Siegal, 2001) amongst other general cognitive abilities that may sometimes account for the apparent social-cognitive ToM deficits observed in stroke populations, irrespective of the hemisphere affected (Yeh & Tsai, 2014).

In an attempt to account for the cognitive demands inherent within these social-cognitive ToM tasks, Apperly and others (Apperly, 2011; Apperly & Butterfill, 2009) proposed a dual route framework of ToM that consists of a slow, complex and flexible social-cognitive route that is heavily underpinned by domain-general cognitive processes, such as executive functions, and a separate, less developmentally-advanced route characterised by speed and efficiency, at the expense of both flexibility and the potential to solve complex problems (e.g., visual perspective-taking, social-perceptual ToM). This theory emphasises the importance of the research findings derived from the use of social-cognitive ToM tasks, however also highlights that it is not the complete picture of ToM.

Social-Perceptual Theory of Mind

Following Baron-Cohen, Jolliffe, Mortimore, and Robertson's (1997) study that involved the development of a task that tapped into the social-perceptual component of ToM, the Reading the Mind in the Eyes task (RMET), there has been increasing interest in investigating this aspect of ToM within clinical populations, including those with acquired brain injury. Participants completing the RMET are presented with a selection of black-and-white pictures consisting of the eye region of human faces and are subsequently asked to select a word from two-options that best describe what the person within the photograph might be feeling or thinking. It has since been revised (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), so as to address some of the limitations within the earlier version, including increasing the number of items and possible forced-choice responses to enhance its capacity to differentiate between people with impaired and preserved social-perceptual ToM.

There have been a number of studies exploring the performance of heterogeneous neurological populations on the RMET. Similar to evidence base for social-cognitive ToM, impaired performance has generally been observed (Havet-Thomassin, Allain, Etcharry-Bouyx, & Le Gall, 2006; Henry, Philips, Crawford, Ietswaart, & Summers, 2006; Martory et al., 2015; Milders, Fuchs, & Crawford, 2003). However, in contrast to evidence derived from social-cognitive ToM tasks (see previous sub-section), these social-perceptual findings may be less of a reflection of the differences – with respect to domain-general cognitive functioning – between groups with acquired brain injury and healthy controls. Indeed, Baron-Cohen et al. (2001) argued that the RMET involved unconscious, rapid and automatic processes that relied less on general cognitive abilities. They also revealed that performance on the task was independent of non-social aspects of intelligence, indicating its purity as a measure of ToM. Although evidence from a recent meta-analysis suggests that this social-perceptual ToM task does in fact place some demand on general intellectual functioning, this is minimal (Baker, Peterson, Pulos, & Kirkland, 2014). Similarly, dual-task experimental studies have revealed that the RMET involves some inhibitory processing, although this was vastly inferior to the incidental processing demands within Happe's (1994) Strange Stories (social-cognitive ToM) task, which was reliant on a range of executive functions, including inhibition, monitoring and updating working memory and switching (Bull, Philips, & Conway, 2008; McKinnon & Moscovitch, 2007). In contrast, Ahmed and Miller (2011) revealed that no executive function could account for the variance in RMET performance within adults aged between 18 and 27 years, although word-reading ability was a contributing factor. This discrepancy may be explained by the involvement of older adults in the earlier studies (Bull et al., 2008; McKinnon & Moscovitch, 2007), who might be more reliant on compensatory cognitive resources/neural substrates (e.g., executive processes) than younger adults to complete complex tasks (e.g., RMET) (Castelli et al., 2010; Reuter-Lorenz et al., 2000) as a result of age-related changes in brain regions and white matter tracts crucial to social-perceptual ToM (Cabinio et al., 2015; Moran, Jolly, & Mitchell, 2012).

Alongside the RMET's advantage over social-cognitive ToM tasks of (relative) independence from domain-general cognitive abilities, it has been found to be a better predictor of social communication (Ubukata et al., 2014). They argued that social-perceptual ToM tasks better simulated real-world situations – involving the management of interpersonal interactions and relationships – than social-cognitive ToM tasks. This demonstrates receptivity to Channon and Crawford's (2010) call for "clinical neuropsychology to develop assessment methods that can detect everyday social difficulties and identify which aspects of problem-solving are challenging for each individual, without necessarily requiring real-world observations, which are extremely time-consuming" (pg. 741). However, despite the demonstrable ecological validity of the RMET with respect to its predictive value on everyday tasks (veridicality), the use of static stimuli and reliance on the visual modality within the task is not representative of real-world ToM dilemmas (lacking verisimilitude). Turkstra (2008) found picture-based tasks (e.g., RMET) alongside narrative ToM tasks – due to the absence of cues that are readily available within everyday interpersonal interactions – might overestimate the ToM deficits typically observed in populations with acquired brain injury, emphasising the importance of exploring the application of ToM tasks with verisimilitude. This is supported by a recent investigation that found the social-perceptual ToM construct was better tapped by dynamic film-based stimuli than the RMET (Oakley, Bird, Brewer, & Catmur, 2016).

In line with Stone and Hynes' (2011) assertion that, "tests that relate to real-world social functioning are valuable regardless of whether the tests are sensitive to specific regions of brain damage" (pg. 472), the present study will explore the use of a task with verisimilitude, known as the Cambridge Mindreading Face-Voice Battery (CAM; Golan, Baron-Cohen, & Hill, 2006) within a heterogeneous stroke population (i.e., consisting of stroke survivors with diverse brain lesions). The CAM requires participants to decode the mental state of a human protagonist based on a dynamic voice or video clip of the actor. It is strongly correlated with the RMET, however provides a more thorough investigation of social-perception or in other words, the efficient ToM pathway defined by Apperly (2011), through both auditory and visual modalities, with the latter involving a video-clip consisting of actors in motion displaying a particular mental state (see Methods for further details). By exploring the extent to which the CAM can be used to differentiate between a heterogeneous stroke and healthy control sample, the current study aims to evaluate the utility of the CAM in assessing the ToM abilities of stroke survivors

Hypotheses

H1: Stroke survivors will perform poorer than healthy control participants on the CAM (verbal and visual ToM).

H2: Performance on the CAM (verbal and visual component) will predict membership to group (stroke or healthy control)

Methods

Participants

Stroke survivors were recruited from three National Health Service (NHS) community neurorehabilitation teams and an NHS neuropsychology team in the South East of England. People with stroke that met the inclusion criteria (see below) were identified by a clinician previously or currently involved in their care and were provided with an information sheet (Appendix B). If verbal consent was provided, stroke survivors were approached by the principal researcher who provided further information and completed a brief screening assessment based on the exclusion criteria (see below). Out of the 41 stroke patients that consented for their details to be passed on to the researcher, 25 participated. Reasons for this attrition included stroke survivors meeting an exclusion criterion, lack of responsiveness to contact from the researcher or the participant deciding not to participate. After exclusions based on the above, 22 eligible stroke patients between the ages of 36 and 89 years (M = 63.3, SD = 13.4) participated in the study. With consent from the stroke survivors, their partners were contacted and if agreeable following screening, they were provided with an information sheet (Appendix C) and recruited as healthy control participants. Further healthy controls were recruited via advertisements on social media outlets. Twenty eligible healthy control participants between the ages of 37 and 83 years (M = 64.4, SD= 10.7) took part in the study. The stroke and healthy control sample did not significantly differ in terms of age and education (see Table 1 for participant demographics).

Participants were included on the basis of having the capacity to provide informed consent in written form (Department of Health, 2007). In line with the Mental Capacity Act, clinicians assumed potential participants in the stroke sample had capacity unless there were reasons to believe this was not the case. The same approach to capacity was adopted by the primary researcher with regards to the healthy controls. A lack of capacity was indicated if a potential participant was unable to understand and/or retain the information relevant to their decision to participate, use this information as part of a decision-making process and/or communicate their decision. Only participants aged 18 years or above, with normal or corrected-to-normal vision and hearing, an ability to tolerate up to two hours of cognitive testing across one or two sessions, and fluency in English language were included. Stroke survivors were excluded if they self-reported any other neurological condition besides stroke. Healthy controls were included on the basis that they self-reported having no neurological condition, including stroke. Exclusion criteria across the stroke and healthy control group included a self-reported formal diagnosis of a severe and enduring mental health problem (i.e., schizophrenia or other psychotic disorders, bipolar disorder, and personality disorder), a formal diagnosis of a neurodevelopmental condition, severe neuropsychological dysfunction (e.g., visual neglect) that may affect test performance, history of chronic substance misuse and a Mini-Addenbrooke's Cognitive Examination (M-ACE; Hsieh et al., 2015) score of 21 or below. Three potential participants in the stroke sample were previously excluded based on their performance on the M-ACE being below the cut-off value, whereas one person was excluded from the healthy control group on the same basis.

In accordance with the Code of Human Research Ethics (British Psychological Society, 2015), informed consent was obtained from all participating stroke survivors (Appendix D) and healthy controls (Appendix E) in written form. For stroke survivors who provided written consent, electronic and paper medical records were either accessed by the researcher or indirectly through clinicians. These data were accessed for the purposes of acquiring information on the nature of their stroke and history of previous stroke (Appendix F).

Table 1

Descriptive and Inferential Statistics for Demographic Variables

Demographics	Stroke	Healthy Control	t/φ_c-statistic	p value
N	**22**	**20**		
Age (years)	M = 63.3 SD = 13.40	M = 64.4 SD = 10.68	t = -0.27	.79
Education (years)	M = 12.3 SD = 2.07	M = 13.2 SD = 2.50	t = -1.24	.22
Gender	**Male = 13** **Female = 9**	**Male = 6** **Female = 14**	φ_c = 0.29	.06
Dominant Hand	**Left = 1** **Right = 21**	**Left = 5** **Right = 15**	φ_c = 0.29	.06
M-ACE (max = 30)	M = 26.3 SD = 2.51	M = 28 SD = 2.03	t = -2.37*	.02
Processing Speed	M = 28.8 SD = 7.92	M = 32.9 SD = 7.08	t = - 1.76	.09
DEX-total (max = 80)	M = 28.9 SD = 15.61	M = 20.8 SD = 9.20	t = 2.03*	.05
Anxiety (max = 21)	M = 9.5 SD = 5.27	M = 4.9 SD = 2.53	t = 3.55**	<.001
Depression (max = 21)	M = 6.3 SD = 3.46	M = 2.2 SD = 2.16	t = 4.63**	<.001

Note. Descriptive statistics presented in frequency are in boldface. N = number; M-ACE = Mini-Addenbrooke's Cognitive Examination; DEX-total = Dysexecutive Questionnaire total score; M = Mean; SD = standard deviation; t = statistics; φ_c = Cramér's V.
*p < .05. **p < .01

Materials

General Cognition.

The Mini-Addenbrooke's Cognitive Examination (M-ACE; Hsieh et al., 2015) was used to assess general cognition. The M-ACE is an abbreviated adaptation of the Addenbrooke's Cognitive Examination – Revised (Mioshi, Dawson, Mitchell, Arnold, & Hodges, 2006) and evaluates orientation (maximum score of 4 points), immediate verbal memory (maximum of 7), clock-drawing (maximum of 5), animal name/category fluency (maximum of 7) and delayed verbal memory (maximum of 7). A total of 30 points are available from the cognitive screening tool. The recommended cut-off score of 21 yielded a sensitivity of 61% and 100% specificity for dementia (Hsieh et al., 2015). It has a good internal consistency (α = .83) and concurrent validity (r_s = .83) using the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975).

Processing Speed.

A modified version of the Information Processing A task in the Adult Memory and Information Processing Battery (Vlaar & Wade, 2003; see also Coughlan & Hollows, 1985) was used to measure processing speed. The test consists of 105 rows of five 2-digit numbers (Appendix G), and the participant is instructed to call out the second highest number in each row of five numbers following a demonstration by the researcher and performing the practice trial of 5 rows. The participant is instructed to complete as many rows as possible within two minutes. The examiner or participant switched over to another laminated paper stimuli (consisting rows of numbers) once a page had been completed by the participant. The total score was calculated as the number of correct responses made within the time limit subtracted by the number of incorrect answers.

Mood.

The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) was used to evaluate the extent to which participants were experiencing symptoms of anxiety and depression. The HADS consists of 14 items, each of which can be responded to using a four-point scale ranging from 0 to 3. Possible scores for the depression and anxiety constructs both range from 0 to 21, higher scores indicating a greater extent of anxiety or depression.

Theory of Mind.

ToM was assessed using the Cambridge Mindreading Face-Voice Battery (CAM; Golan et al., 2006). It consists of two separate tasks that evaluate the recognition of 20 different complex emotion and mental state concepts from visual (face) or verbal (voice) cues. These tasks were presented via laptop computer and ran on DMDX experimental software (Forster & Forster, 2003). For the Voice task, following an instruction screen and two practice items, the participant listened to fifty brief audio clips whereby an actor expressed different emotional intonations. In the case of the Face task, following the instructions and practice trials, participants were presented with fifty 3-5 second silent video clips of actors portraying different emotions through their facial expression. A set of laminated sheets with definitions of each possible emotion/mental state word response was available during the experimental session (see Appendix H), which participants were encouraged to use if they were unsure of a word during any trial. There was no time limit for responding to items.

Items within both tasks were randomly presented. After the presentation of each stimulus (i.e., watching a video clip or listening to a voice recording), participants were instructed to select an adjective, from four options, that best described the mental state being conveyed within the clip. The Face (visual) and Voice (verbal) ToM score for participants was indicated by calculating the percentage of correct responses within the respective tasks. The CAM has good test-retest reliability ($r = .94$ and .81 for the Face and Voice component, respectively) and strong concurrent validity ($r = .74$ for the Face task and .62 for the Voice task) using the RMET (Baron-Cohen et al., 2001) and Reading the Mind in the Voice task (Golan, Baron-Cohen, Hill, & Rutherford, 2007), respectively.

Executive Function.

The DEX questionnaire (Wilson, Evans, Emslie, Alderman, & Burgess, 1998) was used as a measure of executive functioning. It is a widely used 20-item self-report questionnaire in Likert format. Using a 5-point scale ranging from never (0 point) to very often (4 points), participants are instructed to rate each item on the frequency by which they experience executive function-related difficulties within their daily life. Possible scores for the DEX range from 0 to 80, higher scores indicating a greater extent of executive dysfunction.

Design

The study utilised a between-groups design to enable comparisons between stroke survivors and healthy controls. To test hypothesis 1, participant group (stroke or healthy control) served as the independent variable and verbal and visual ToM (measured by the CAM) were the dependent variables. As hypothesis 2 was concerned with the extent to which the CAM scores could predict whether a person belonged to the stroke or healthy control sample, group membership was entered as the dependent variable, whereas performance on the CAM Face and Voice tasks served as independent variables within a discriminant function analysis.

Data Analysis

Data were stored and analysed using IBM SPSS Statistics version 23. Prior to commencing statistical analysis, the data were checked for any violations of parametric assumptions (Appendix I). As there were significant differences between the M-ACE scores of the stroke and healthy control samples (see Table 1), a one-way Analysis of Covariance (ANCOVA) with the M-ACE score as a covariate was completed alongside an independent sample t-test for parametric between-group comparisons (see Appendix J for ANCOVA assumption checks[4]). Discriminant function analysis was used to predict group membership (stroke or healthy control) from CAM performance.

As part of the experimental design planning phase, an a priori power calculation using the effect size from a previous study (Yeh & Tsai, 2014) was completed to estimate an appropriate sample size for the present investigation. The alpha level was set at the conventional level of 5% and power was placed at 95%. Eleven participants for each group was estimated for the between-group parametric comparisons (see Appendix K). In comparison to previous literature, Yeh and Tsai's study had the largest sample size, so was deemed the most suitable paper from which to derive power calculations for the present study.

[4] The ANCOVA assumption of linearity of regression was violated for the between-group comparison of CAM Face (Visual) and Voice (Verbal) tasks

Procedures

Before beginning the experiment, participants were informed of their right to withdraw from the study without giving reason. If the primary investigator suspected that a participant was becoming distressed or fatigued during the experiment, a rest break was suggested. In such a case, the researcher also asked participants whether they would prefer to continue the experiment on another scheduled occasion.

Participants completed the experiment within their home (following local NHS Trust lone-working policy) or Trust sites across the South East of England. The cognitive tests and self-report questionnaires were completed within one or two sessions. It took the stroke survivors between 90 and 180 minutes to complete the experiment, whereas the healthy control participants generally completed the battery of tasks and questionnaires in under two hours.

For laptop computer-based tasks (i.e., CAM), participants were seated at a table in front of the laptop screen. The principal investigator was seated at an angle that enabled full view of the screen, so that support could be offered during practice trials. To minimise measurement errors from modality presentation order (verbal vs. visual) during the computerised tasks, half of the stroke and healthy control sample were presented with the CAM Voice task before the CAM Face task, whereas the remaining participants' completion of the Voice task was preceded by its visual counterpart. All collected data were pseudonymised using participant codes. Physical data were stored in a lockable drawer and separated from completed consent forms. Electronic data were stored in an NHS Trust encrypted and password-protected USB flash drive.

Results

An independent sample t-test was initially presented for the first hypothesis, following which a re-analysis was conducted with M-ACE scores as a covariant within an ANCOVA.

Between-Group Theory of Mind Performance

It was hypothesised that stroke survivors will perform poorer than the healthy controls on the verbal ToM task (CAM Voice). An independent sample t-test comparing the groups revealed that there were no significant differences, $t(40) = -1.33$, p (one-tailed) $= .09$, between the CAM Voice accuracy of the healthy control ($M = 75.25\%$, $SD = 10.97\%$) and stroke samples ($M = 70.46\%$, $SD = 12.27\%$). An ANCOVA also revealed that there was no significant between-group difference in CAM Voice after controlling for M-ACE scores, $F(1, 39) = .11$, p (one-tailed) $= .37$.

It was also hypothesised that stroke survivors would perform poorer than the healthy controls on the visual ToM task (CAM Face). An independent sample t-test comparing the groups revealed that there were no significant differences, $t(40) = -.79$, p (one-tailed) $= .22$, between the CAM Face accuracy of the healthy control ($M = 68.10\%$, $SD = 11.38\%$) and stroke samples ($M = 65.36\%$, $SD = 11.09\%$). An ANCOVA also showed no differences between the groups on CAM Face accuracy after controlling for M-ACE scores, $F(1, 39) = .01$, p (one-tailed) $= .47$.

Group Membership Prediction

It was hypothesised that there will be a significant discriminant function of verbal and visual ToM for group membership (stroke or healthy control), however the discriminant analysis revealed a non-significant discriminant function of the CAM, $\chi^2(2) = 1.73$, $p = .42$.

Exploratory Analyses

Given the unexpected non-significant between-group differences and discriminant function of the CAM, it was hypothesised that there would be wide variance in the scores of the stroke sample. As this was confirmed through a physical inspection of the data, an exploratory hierarchical cluster analysis was completed for the purpose of characterising different CAM profiles within the stroke sample. Hierarchical clustering was selected based on the small stroke sample size (Norušis, 2011). In line with a previous study examining ToM clusters in stroke populations (Champagne-Lavau & Joanette, 2009), Ward's method to hierarchical clustering was selected.

Four clusters indicative of distinct ToM performance patterns were revealed (see Figure 1). Four rather than three clusters were selected for the analysis as, on visual inspection, participants 8 and 17's scores appeared qualitatively different from others in the stroke sample, and so a separate cluster for this sub-group was deemed appropriate. This included stroke survivors with preserved performance on the visual ToM task, but superior performance – in comparison to healthy controls – on the verbal ToM task (preserved group), those with a trend towards poorer performance on the verbal ToM task and preserved performance on visual ToM (specific verbal ToM impairment), those with poorer performance on both the verbal and visual ToM tasks (global ToM impairment group) and lastly, two stroke patients that formed a separate cluster, however were found to perform as well as the healthy controls across the verbal and visual ToM tasks (two-sample group). A Kruskal-Wallis Test revealed no significant differences between the clusters with regards to age, $\chi^2(4) = 4.41$, p = .35, and education, $\chi^2(4) = 6.35$, p = .18 (see Table 2 for descriptive statistics). However, the difference between the specific verbal ToM impairment (Mdn = 13 years) and global ToM impairment (Mdn = 11 years) clusters with regards to education was close to significance, U = 9.5, p = .07.

Differences in cognition (general and processing speed) between the stroke subgroups and healthy controls were considered below.

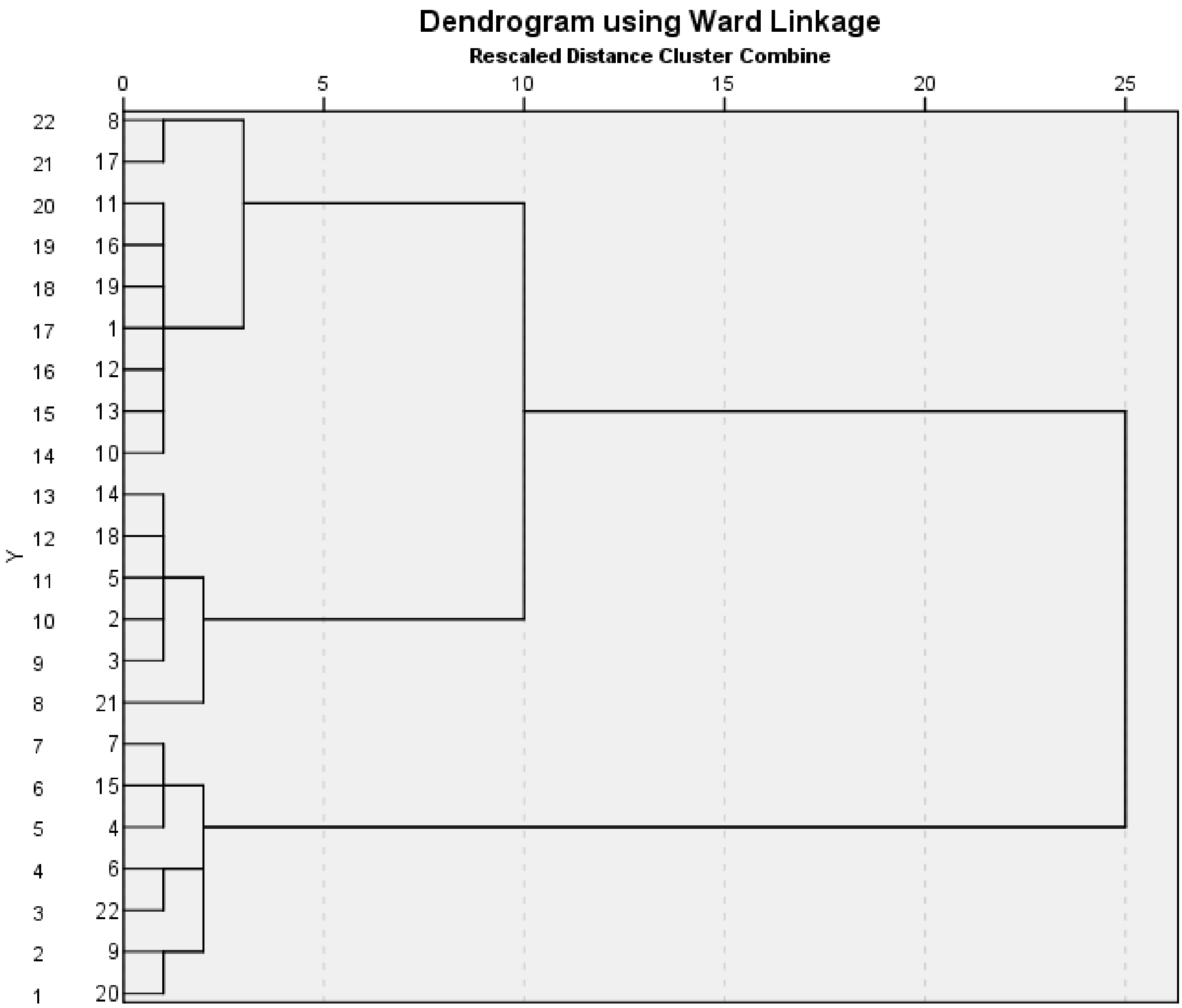

Figure 1. Dendogram using Ward's method on the stroke sample

Global ToM impairment.

This subgroup consisted of six stroke survivors (p2, p3, p5, p14, p18, p21) that performed poorer than the healthy groups on both the verbal ToM, U = 6.50, p = .001) and visual ToM tasks, U = 10.0, p = .002. This pattern of ToM co-occurred with cognitive impairment relative to healthy controls. A Mann-Whitney U test revealed that the global ToM impairment subgroup performed worse than the healthy control sample on processing speed, U = 14.0, p = .01, while the between-group difference – in favour of the healthy control group – with regards to the M-ACE was close to significance, U = 31.50, p = .08.

Preservation in ToM.

This subgroup consisted of seven stroke survivors (p4, p6, p7, p9, p15, p20, p22) who performed better than the healthy control group on the verbal ToM task, U = 34.00, p = .05, while the between-group difference – in favour of the stroke cluster – with regards to accuracy on the visual ToM task was close to significance, U = 37.00, p = .07. There were no significant differences revealed between the preserved stroke cluster and healthy control sample on processing speed, U = 64.50, p = .76, and M-ACE, U = 64.50, p = .76.

Two-sample subgroup (unimpaired).

Only two stroke survivors (p8 and p17) formed this subgroup. Due to the very small sample size of this cluster, Crawford & Howell’s (1998) approach to single-case comparisons was used to compare their performance to the healthy control sample. Both participants showed no deficit for verbal ToM tasks compared to controls, for p8, t(19) = -0.29, p(one-tailed) = 0.39, and for p17, t(19) = -0.29, p(one-tailed) = 0.39. Similarly, neither participant showed deficit for the visual ToM task compared to controls, for p8, t(19) = -1.21, p (one-tailed) = 0.12, and for p17, t(19) = -1.21, p(one-tailed)= 0.12.

Participant 8 showed no deficit for general cognition, t(19) = -0.96, p (one-tailed) = 0.17, however showed deficits for processing speed, t(19) = -2.88, p (one-tailed) = 0.01. On the other hand, participant 17 showed no deficit for general cognition, t(19) = 0.00, p (one-tailed)= 0.50 nor processing speed, t(19) = -1.23, p (one-tailed)= 0.12.

Specific impairment in verbal ToM.

This subgroup consisted of seven stroke survivors (p1, p10, p11, p12, p13, p16, p19) who performed as well as the healthy controls on the visual ToM task, U = 66.50, p = .85), while the between-group difference – in favour of the healthy controls – with regards to accuracy on the verbal ToM task, was close to significance, U = 39.5, p = .09. This subgroup of the stroke sample performed poorer than the healthy controls on the M-ACE, U = 20.50, p < .001), however there was no statistically significant difference with regards to processing speed, U = 53.50, p = .36.

Table 2

Descriptive Statistics for Variables of Stroke Clusters and Healthy Control Sample

Variable	A-VER	GLOB	PRES	TWO	HC
N	7	6	7	2	20
Age (years)	Mdn = 70.0 IQR = 10.0	Mdn = 66.0 IQR = 15.0	Mdn = 60.0 IQR = 19.0	Mdn = 52.0 IQR = N/A	Mdn = 65.5 IQR = 12.8
Education (years)	Mdn = 11.0 IQR = .0	Mdn = 11.0 IQR = 2.0	Mdn = 13.0 IQR = 5.0	Mdn = 11.0 IQR = N/A	Mdn = 11.5 IQR = 4.8
Verbal ToM (%)	Mdn = 70.0 IQR = 4.0	Mdn = 58.0 IQR= 11.5	Mdn = 85.0 IQR = 12.0	Mdn = 72.0 IQR = N/A	Mdn = 75.0 IQR = 18.0
Visual ToM (%)	Mdn = 68.0 IQR = 8.0	Mdn = 50.0 IQR = 4.0	Mdn = 79.0 IQR = 13.0	Mdn = 54.0 IQR = N/A	Mdn = 69.0 IQR = 17.0
Processing Speed	Mdn = 31.0 IQR = 8.0	Mdn = 22.0 IQR = 8.0	Mdn = 31.0 IQR = 10.0	Mdn = 18.0 IQR = N/A	Mdn = 32.5 IQR = 11.0
M-ACE (max = 30)	Mdn = 25.0 IQR = 5.0	Mdn = 25.0 IQR = 4.0	Mdn = 28.0 IQR = 2.0	Mdn = 27.0 IQR = N/A	Mdn = 29.0 IQR = 2.0

Note. A-VER = stroke patients impaired on visual ToM only; GLOB = stroke patients impaired on both verbal and visual ToM; PRES = stroke patients unimpaired on both verbal and visual ToM; TWO = two-sample cluster with unimpaired performance across ToM tasks; HC = healthy controls; M-ACE = Mini-Addenbrooke's Cognitive Examination; Mdn = Median; IQR = Interquartile Range; N/A = not applicable.

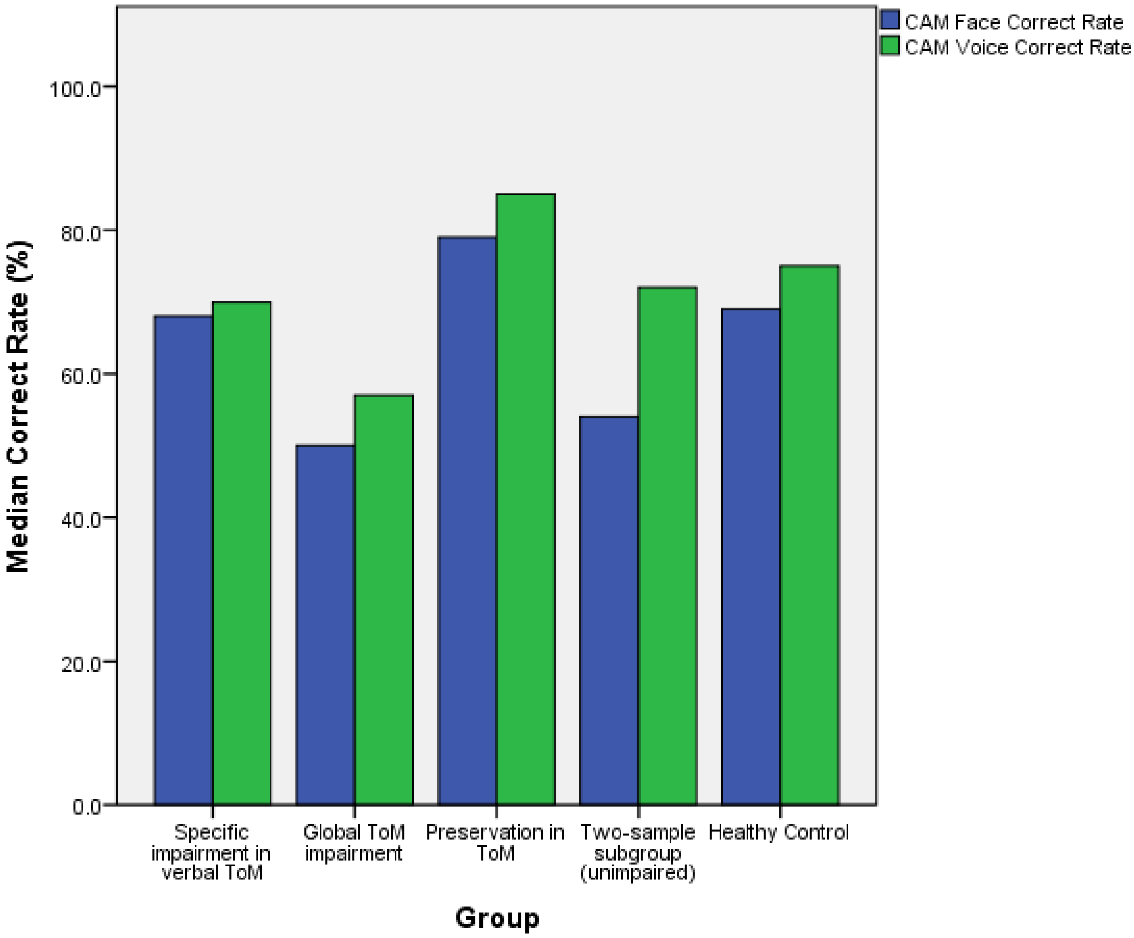

Figure 2. Median Accuracy on the Cambridge Face (Visual Theory of Mind) and Voice (Verbal Theory of Mind) Tasks for the Stroke Clusters and Healthy Control Sample

Discussion

Theory of Mind & Group Differences

The present study sought to evaluate the utility of a relatively novel, dynamic and ecologically-valid test of social-perceptual ToM – the Cambridge Mindreading Face-Voice Battery (CAM) – in stroke populations through investigating its capacity to distinguish between stroke survivors and an age- and education-matched healthy control sample. It was predicted that stroke survivors would perform poorer than healthy controls on the CAM, however no significant differences were identified within both the Face and Voice ToM tasks. Given the aforementioned findings, it is of no surprise that the null hypothesis was accepted for the second hypothesis, which predicted that CAM Face and Voice scores would be able to accurately differentiate between the heterogeneous stroke sample and healthy controls.

These findings contrast with the majority of the social-cognitive (Martin-Rodriguez & Leon-Carrion, 2010) and social-perceptual ToM literature (Henry et al., 2006; Ubukata et al., 2014), which show people with acquired brain injury (including stroke populations) perform poorer than healthy controls on these tasks (Martory et al., 2015; Yeh & Tsai, 2014). It is plausible that the presence of specific cues (motion, intonation, etc.) within the dynamic CAM was sufficient in enabling stroke survivors to accurately decode the mental state of a protagonist, whereas most tasks within the literature were either heavily dependent on domain-general abilities (viz., social-cognitive ToM tasks that rely on the slow route) or in the case of social-perceptual tasks that are underpinned by the efficient ToM route, the artificial nature of the stimuli may have lacked perceptual information that would normally be available within natural environments (e.g., motion patterns) (Turkstra, 2008). However, Turkstra found that patients with moderate to severe acquired brain injury (mostly traumatic brain injury) performed poorer on a video-based ToM task that required participants to make mental state inferences and subsequent predictions based on the interaction between two protagonists (e.g., I think those two people won't want to hang out in the future as they are not getting along).

There are two main factors that may explain why the current study did not reveal differences between the heterogeneous stroke and healthy controls, whereas Turkstra's (2008) study did. Firstly, the video-based task in Turkstra's study tapped into social-cognitive ToM, which the author highlighted was partly dependent on working memory due to the requirement for participants to track the 30-second video clips. Thus, it is possible that the observed ToM deficits are attributable to domain-general executive function impairment within the acquired brain injury sample. Although the cognitively-demanding social-cognitive ToM is also relevant to social functioning (Apperly & Butterfill, 2009), the likelihood that the video-based task is tapping into a different construct to the CAM may explain the discrepancy with the present study. This is supported by recent research that identified non-significant relationships between the RMET and social-cognitive tasks (e.g., Faux Pas) (Ahmed & Miller, 2011; Xi et al., 2013). Secondly, Turkstra's study predominantly involved people with severe traumatic brain injury, which is likely to result in widespread brain lesions – due to diffuse axonal injury (Skandsen et al., 2010) – and as a result, greater level of global impairment than the stroke sample involved in the present study.

To the best of my knowledge, there are only two recent studies that have utilised realistic and dynamic stimuli to measure ToM in stroke populations (Leigh et al., 2013; Oishi et al., 2015). Leigh et al. found 14 out of 27 of the stroke patients with right hemisphere damage – involved in their study – were impaired on a task that required participants to infer the affective state of a protagonist based on short videotapes and narrated stories. They found 9 (out of the 14) stroke patients had damage to the brain regions in the so-called theory of mind network (Saxe, 2006; Saxe, Carey, & Kanwisher, 2004). Oishi et al. later linked this social-cognitive (affective) ToM deficit to damage to the uncinate fasciculus (white matter tract that connects parts of the limbic system [e.g., amygdala] to prefrontal regions). As the lesion data within the present study was mostly unavailable, limited comparisons can be made to these previous investigations. However, it remains a possibility that the heterogeneous stroke sample involved in the current study generally had lesions in brain areas distinct from the ToM network, namely the medial prefrontal cortex, posterior cingulate cortex, temporoparietal junction/superior temporal sulcus and temporal poles (Carrington & Bailey, 2009), which would explain the present findings. Indeed, Participant 21 who had a left temporal lobe lesion (which consists of the amygdala) and Participant 5 who had prefrontal lesions were found to have both visual and verbal social-perceptual ToM deficits in the present study (see Appendix F). Nevertheless, the discrepancy with previous studies may not be unexpected considering the CAM taps into what Baron-Cohen et al. (2001) referred to as the first step in ToM, thus it may be more crystallised and less likely – than complicated social-cognitive ToM tasks – to be affected by an acquired brain injury endured during adulthood.

Furthermore, these previous studies (Leigh et al., 2013; Oishi et al., 2015) recruited neurologically-intact controls as confirmed by magnetic resonance imaging, whereas the present study relied on healthy controls self-reporting no acquired brain injuries. In comparison to the CAM female norms (Golan et al., 2006), the healthy controls in the present study – which predominantly consisted of female participants – scored under two and four standard deviations below the mean on the Voice and Face tasks components of the CAM, respectively. It is possible that there was a significant presence of undiagnosed neurological and/or neurodevelopmental conditions within the healthy controls, which may have minimised between-group differences with the stroke sample. Although, considering Golan et al. mostly involved young adults (M = 27.1 years) as their healthy control group to develop these norms, whereas the average age of the present study's controls was 64.4 years, the aforementioned CAM disparity between healthy controls may be attributed to the well-documented effects of older age on social-perceptual and social-cognitive ToM task performance (Henry, Phillips, Ruffman, & Bailey, 2013).

Although the CAM was unable to accurately distinguish between stroke and healthy controls in the present study, it was found to be able to allocate 90% of adults with high-functioning autistic spectrum condition and healthy controls to their correct groups (Golan et al., 2006). This contrast might suggest that different processes underpin the poor ToM performance of adults with autistic spectrum condition and those with acquired brain injury observed within the literature. It is plausible that there is a core deficit in decoding mental states from cues for people with autistic spectrum condition (explaining why poor performance in social-perceptual ToM tasks is still observed when dynamic cues are readily available), whereas the majority of apparent deficits found in stroke and other acquired brain injury populations may be attributable to deficits in domain-general abilities, including executive functioning and pragmatic language (Apperly, 2011). Nevertheless, the present study is the only investigation that has utilised dynamic stimuli to explore social-perceptual ToM abilities within stroke populations, with other similar adult studies having involved people with unidentified or absent lesions, such as adults with autistic spectrum condition (Golan et al., 2006, 2007) or healthy adult parents of children with autistic spectrum condition (Tajmirriyahi, Nejati, Pouretemad, & Sepehr, 2013).

Fragmentation of Theory of Mind

The exploratory cluster analysis revealed four subgroups within the heterogeneous stroke sample based on ToM performance, three of which appeared distinct from the healthy controls. This included a stroke subgroup with impairments across the verbal and visual ToM tasks, a group that performed better than healthy controls on verbal ToM (while their more accurate performance on the visual ToM task approached significance) and lastly, a subgroup who were preserved in verbal and visual ToM (although their poorer performance on verbal ToM approached significance). These subgroups had differing patterns of performance in domain-general cognitive abilities, namely, general cognition (as measured by the M-ACE) and processing speed. However, given the lack of detailed and consistent lesion data obtained within the present study, conclusions on specific brain region-behaviour relationships cannot be drawn, however the pattern of impairment and preservation across verbal and visual ToM is indicative of the fractionation of ToM by presented modality. This is in contrast to previous functional magnetic resonance imaging studies (Carrington & Bailey, 2009; Mar, 2011; Schurz, Radua, Aichhorn, Richlan, & Perner, 2014) which have revealed a core ToM brain network irrespective of the task type (social-perceptual vs. social-cognitive) or modality (visual vs. verbal).

However, both the findings of these previous neuroimaging studies and the current investigation could be accounted for by Cabeza, Ciaramelli, and Moscovitch's (2012) overarching account of brain functioning, which proposes the idea that functional subdivisions within the brain underpin specific aspects of global cognitive function (e.g., ToM) supported by broad brain regions (e.g., ToM network). Thus, activation in specific brain regions – observed in previous neuroimaging studies – may not necessarily suggest that they are crucial to successfully completing ToM tasks, although as Apperly (2011) implied, lesions in these subdivisions may contribute to the many reasons (executive dysfunction, impaired perspective-taking, pragmatic deficits, etc.) people with acquired brain injury might perform poorly on ToM tasks, which may have been less prevalent within the present stroke sample. This explanation is consistent with a single-case study involving a female patient (G.T.) with extensive bilateral damage to the medial frontal lobe who presented with executive dysfunction, however was relatively preserved across a range of social-cognitive tasks, including the Strange Stories and Faux Pas task (Bird et al., 2004). As the authors argued, spared areas of G.T.'s medial frontal lobes may have been sufficient to subserve her ToM abilities, although – as per the overarching theory – this may have been made possible due to preservation of other functional subdivisions contributing to ToM (i.e., other regions within the ToM network) alongside preserved areas of the medial prefrontal cortex. This hypothesis is further supported by a recent experimental investigation by Samson, Houthuys, and Humphreys (2015), which revealed that general executive dysfunction – similar to that exhibited by G.T. – does not necessarily result in deficits to the self-perspective inhibition functions crucial to successful performance in traditional false-belief tasks.

Furthermore, the overarching perspective applied to ToM (Apperly, 2010; Cabeza et al., 2012) – which suggests different regional subdivisions and cognitive processes contribute to ToM – is consistent with the exploratory findings within the present study, which revealed that the stroke subgroup with a global ToM impairment (verbal and visual) processed information slower than the healthy controls. Also, the p-value (.08) for the difference between this global ToM impaired subgroup and the healthy controls with regards to global cognition – indicating poorer performance – was close to significance. It is plausible that this non-significant difference is attributable to the insufficient experimental power within the non-parametric analysis used to detect a between-group difference, resulting in Type II error. Similarly, the subgroup with (likely) specific verbal ToM impairment performed poorer than the healthy control on the general cognition measure. Indeed, these findings are in line with the view that ToM abilities may be underpinned by a myriad of domain-general processes (e.g., semantic memory), which are themselves innervated by diverse brain regions (Frith, 2007; Legrand & Ruby, 2009).

On the other hand, the preserved stroke subgroup performed better than the healthy controls on the verbal ToM task, while their superior performance on the visual ToM task approached significance (p = .07). This cluster did not differ from the healthy control group with respect to general cognition or processing speed, although when compared to the subgroup with a global ToM impairment, they were better educated (p = .07). Despite this education between-group difference not quite meeting the significance criterion, given the exploratory nature of these results, it may offer a valid explanation for the preservation of ToM in this subgroup. Indeed, these findings are consistent with the cognitive reserve hypothesis (Kesler, Adams, Blasey, & Bigler, 2003) which suggests that greater academic attainment may abate vulnerability to cognitive deficits following acquired brain injury, if it is assumed similar processes may underpin ToM. This hypothesis is supported by studies involving social-cognitive and social-perceptual ToM tasks that have found education to be a significant contributing factor to performance (Oishi et al., 2015; Yildirim et al., 2011). Nevertheless, these tentative conclusions based on very small samples, particularly those derived from marginally non-significant findings, will need to be explored within future studies in neuropsychology. Despite this limitation, the involvement of stroke survivors rather than people who have experienced traumatic brain injury is an advantage with respect to the former having less widespread brain lesions (Martin-Rodriguez & Leon-Carrion, 2010), thus enabling these tentative hypotheses (e.g., ToM fractionation).

Taken together, these findings emphasise the importance of assessing social-perceptual ToM across auditory and visual modalities, and as such, the use of the

RMET in isolation may not be sufficient in capturing this construct within stroke survivors.

Limitations

The present investigation has some limitations, including the lack of detailed lesion data to enable firm brain-behaviour conclusions, and reliance on the self-reported absence of neurological and neurodevelopmental conditions within the healthy controls. Furthermore, the omission of an additional ToM measure (e.g., RMET), social functioning assessment tool, control tasks for the CAM (e.g., Gender Identification task, Basic Emotion Recognition task; see Baron-Cohen et al., 1997; 2001) that could rule out potential confounds (impairments in visual perception/memory, emotion recognition, etc.) and lack of detailed cognitive assessment tools (besides a cognitive screening measure and a test of processing speed) limits the conclusions that can be made within the current study. This is particularly with regards to localising the brain regions and/or domain-general cognitive functions that may underpin performance on the CAM as well as its clinical implications. Nevertheless, upon further investigation, the CAM may offer a more ecologically-valid way of assessing social-perceptual ToM in stroke populations. This will have implications for identifying people who may benefit from ToM remediation interventions (Lundgren & Brownell, 2015) and tailoring them accordingly. Although, the psychometric assessment of a complex ability such as ToM may be somewhat reductionist, thus future studies may consider observational tools to capture the richness of this aspect of social cognition.

With regards to sample demographics, there were more men than women in the stroke sample, whereas there were more women than men in the healthy control sample (p = .06). Previous research has revealed women perform better in visual social-perceptual tasks, including the CAM Face task (Baron-Cohen et al., 2015; Golan et al., 2006), indicative of the importance of gender-matching. Nevertheless, the stroke sample – as a whole – appeared to perform as well as the healthy controls on the CAM, and as such, the imbalanced samples may have had less implications in this instance. As there are no age-norms for the CAM, the extent to which the healthy control sample in the present study represents a typical adult population is unclear. Norms for middle and late adulthood should be established in future studies using the CAM.

Although the use of stroke survivors' partners as control participants facilitated well-matched comparison samples, the knowledge that their spouse was also going to complete the same cognitive battery may have influenced their performance (i.e., through exacerbated performance anxiety). Furthermore, as most participants were tested in their homes, precise environmental control was not possible (e.g., noise, lighting), which may have had implications for their performance on the cognitive measures and thus, the internal validity of the findings. Lastly, the stroke sample were recruited from community teams, who despite attempts to recruit a representative sample, were more likely to refer high-functioning stroke survivors based on clinical rationale.

Future studies

In addition to addressing the aforementioned limitations, more elaborate single- and/or multiple-case design studies investigating the regions affected within the differentially

ToM-impaired stroke clusters (e.g., specific verbal ToM deficits, global ToM deficits) should be considered. As well as exploring the brain-behaviour relationships, it would be valuable to investigate the cognitive processes that might underpin these hypothesised associations in combination with neuroimaging technology (e.g., functional magnetic resonance imaging) to explore possible functional subdivisions. There have been preliminary findings suggestive of the importance of specific brain regions (cerebellum and temporal lobes, etc.) in ToM task performance (Gerschcovich, Cerquetti, Tenca, & Leiguarda, 2011; Xi et al., 2013), however this may benefit from replication using ecologically-valid ToM tasks, such as the CAM.

Conclusion

The present study is the first investigation exploring social-perceptual ToM abilities in stroke survivors using a dynamic and ecologically-valid measure of the construct, which in this case was the Cambridge Mindreading Face-Voice battery (CAM). No significant differences in ToM performance were revealed between the heterogeneous stroke and age- and education-matched healthy control participants, and similarly, performance on the CAM could not accurately distinguish between stroke survivors and healthy controls. The results suggest that the ToM impairments observed in previous neuropsychological studies involving heterogeneous stroke and other types of acquired brain injury (e.g., traumatic brain injury) survivors may be attributable to the absence of cues reflective of real-world interactions (e.g., motion) in the artificial social-perceptual tasks administered, or the use of social-cognitive ToM tasks, which are likely to be affected by acquired brain injury due to this aspect of ToM being heavily dependent on other cognitive processes (e.g., ability to inhibit self-perspective). Lastly, the exploratory findings of differential ToM deficits (e.g., specific verbal ToM impairment, global ToM impairment) point towards a functional fractionation of social-perceptual ToM abilities, which appear to be dependent on the nature of the perceptual cues available to a person (face/visual vs. voice/auditory). Although, given the nature of these exploratory findings, this controversial fractionation hypothesis is tentative and will need further investigation within lesion studies with greater experimental power combined with neuroimaging technology.

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Isaac Oluwamayowa Akande BSc (Hons), MSc

MAJOR RESEARCH PROJECT

Section C: Appendices of Supporting Material

Salomons Centre for Applied Psychology
Canterbury Christ Church University

MAY 2017

Appendix A: SPSS output for Sedeno et al.'s (2016) study

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Appendix B: Participant information sheet (stroke sample)

Canterbury Christ Church University

Salomons Centre for Applied Psychology

DO EXECUTIVE FUNCTIONS PARTIALLY UNDERLIE THEORY OF MIND IN ADULTS?

PARTICIPANT INFORMATION SHEET

Principal Investigator
Isaac Akande
Email: i.o.akande66@canterbury.ac.uk
Mobile number: 07498769752

Hello. My name is Isaac Akande, and I am a doctoral student supported by Dr Edyta Monika Hunter at Canterbury Christ Church University [CCCU]. I would like to introduce a project I am conducting looking at whether executive functions (thinking skills that help us make decisions during unfamiliar situations) are related to another thinking skill known as theory of mind, which is our capacity to process the thoughts and feelings of self and others. Service users (people who have experienced stroke) were involved in reviewing the Participant Information Sheet and we have taken into account their opinions within the design of the study.

Purpose of and Background to the Research
The evidence concerning the relationship between theory of mind and executive functions following stroke is mixed, with some studies suggesting there exists a relationship, whereas others do not. The present investigation will attempt to clarify this issue. You have been invited to participate as you have experienced stroke and are eligible to participate within the initial screening procedure.

What would taking part involve?
To begin with, you will be required to meet with me to complete a short eligibility task. If it is determined that you will not be eligible, I will discuss this with you, following which the experiment will be stopped. If the screening task indicates that you are eligible, you will be invited to complete some thinking skill tasks, including computer (laptop) exercises. Please do not worry if you have limited computer skills as this will not be required. I will also ask you to complete a short questionnaire. Furthermore, some brief questions will be asked, including your age.

If you would like to take part in this study, it can take place at a suitable location for you, including your home. Travel expenses (up to £5.00) can be reimbursed. The session will take around one-and-a-half hours and will include regular rest breaks if needed. Although if necessary, the tasks can be split across two separate days. With your permission, I will access your medical records to acquire information specifically regarding your stroke, including which area of the brain it affected. This will not be linked with any personal information, therefore anonymity will be maintained.

What are the potential benefits of taking part?
Although I cannot guarantee that you will experience any direct benefit from taking part within the investigation, research in general does deliver wider benefits to society, and this study may potentially benefit others who may experience stroke in the future. Participants will be asked if they would like to receive a copy of the findings upon completion of the project.

What are the potential disadvantages and risks of taking part?

Canterbury Christ Church University

Salomons Centre for Applied Psychology

Whilst there are no foreseeable strong risks of harm, some people might find completing tasks and questionnaires a tiring and/or distressing experience. I will advise you to nominate someone within your life (friend, family or professional) to be available for support during the study; nevertheless I will also be available before, during and after the investigation. It is envisaged that the research findings will be submitted to a peer-reviewed journal for publication, however individual participants will not be identifiable from the report as the findings will be fully anonymised.

What if something goes wrong?
If you have a concern about any aspect of this study, you should ask to speak to the researchers who will do their best to answer your questions on the following telephone number **0333 011 7070**. If you remain unhappy and wish to complain formally, you can do this by contacting the [redacted] Trust [redacted] on [redacted] or through sending an email to [redacted].

What will happen if I don't want to carry on with the study?
If you decide to take part in the study, you are free to withdraw at any time without having to give a reason, following which we will extract and destroy all your data.

Will my information be kept confidential?
All data and personal information will be stored securely in accordance with the Data Protection Act 1998. To maintain confidentiality, direct personal identifiers will be kept separately from other information, including experiment data. When the study is completed, all direct identifiers will be destroyed and only fully anonymised data will be stored within CCCU - in line with the Data Protection Act 1998 and the University's own data protection requirement - for up to 10 years, following which it will be destroyed. If you decide to take part I will ask for the name and contact details of your registered General Practitioner (GP). In the unlikely event that I have significant concerns for your well-being during the study, I will inform your GP, however this would be discussed with you beforehand. Confidentiality cannot be guaranteed if I have concerns that you or someone else might be at risk of harm.

Who has reviewed this study?
NHS research is monitored by an independent group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and given favourable opinion by Dulwich - London Research Ethics Committee.

What next?

If you would like to participate within the study, or have any questions or concerns about the investigation, please contact me, Isaac Akande, by mobile number: 07498769752, or by email at: i.o.akande66@canterbury.ac.uk. You can also contact my supervisors, Dr Edyta Monika Hunter by telephone on: **0333 011 7070** and Dr Lucie Goddard on [redacted] For advice on whether you should or should not participate, I will recommend you seek guidance from the person you may have nominated (friend, family or professional) for support during the study.

Thank you for your time and interest.

Version 1.2
Date: 3rd March 2016

Appendix C: Participant information sheet (healthy control sample)

Canterbury Christ Church University

Salomons Centre for Applied Psychology

DO EXECUTIVE FUNCTIONS PARTIALLY UNDERLIE THEORY OF MIND IN ADULTS?

PARTICIPANT INFORMATION SHEET

Principal Investigator
Isaac Akande
Email: i.o.akande66@canterbury.ac.uk
Mobile number: 07498769752

Hello. My name is Isaac Akande, and I am a doctoral student supported by Dr Edyta Monika Hunter at Canterbury Christ Church University [CCCU]. I would like to introduce a project I am conducting looking at whether executive functions (thinking skills that help us make decisions during unfamiliar situations) are related to another thinking skill known as theory of mind, which is our capacity to process the thoughts and feelings of self and others. Service users (people who have experienced stroke) were involved in reviewing the Participant Information Sheet and we have taken into account their opinions within the design of the study.

Purpose of and Background to the Research
The evidence concerning the relationship between theory of mind and executive functions following stroke is mixed, with some studies suggesting there exists a relationship, whereas others do not. The present investigation will attempt to clarify this issue. You have been invited to participate as you have **not** experienced stroke and are eligible to participate within the initial screening procedure.

What would taking part involve?
To begin with, you will be required to meet with me to complete a short eligibility task. If it is determined that you will not be eligible, I will discuss this with you, following which the experiment will be stopped. If the screening task indicates that you are eligible, you will be invited to complete some thinking skill tasks, including computer (laptop) exercises. Please do not worry if you have limited computer skills as this will not be required. I will also ask you to complete a short questionnaire. Furthermore, some brief questions will be asked, including your age.

If you would like to take part in this study, it can take place at a suitable location for you, including your home. Travel expenses (up to £5.00) can be reimbursed. The session will take up to one-and-a-half hours and will include regular rest breaks if needed. Although if necessary, the tasks can be split across two separate days.

What are the potential benefits of taking part?
Although I cannot guarantee that you will experience any direct benefit from taking part within the investigation, research in general does deliver wider benefits to society, and this study may potentially benefit people who experience stroke in the future. Participants will be asked if they would like to receive a copy of the findings upon completion of the project.

What are the potential disadvantages and risks of taking part?
Whilst there are no foreseeable strong risks of harm, some people might find completing tasks and questionnaires a tiring and/or distressing experience. I will advise you to nominate someone within your

Canterbury Christ Church University

Salomons Centre for Applied Psychology

life (friend, family or professional) to be available for support during the study; nevertheless I will also be available before, during and after the investigation. It is envisaged that the research findings will be submitted to a peer-reviewed journal for publication, however individual participants will not be identifiable from the report as the findings will be fully anonymised.

What if something goes wrong?
If you have a concern about any aspect of this study, you should ask to speak to the researchers who will do their best to answer your questions on the following telephone number **0333 011 7070**. If you remain unhappy and wish to complain formally, you can do this by contacting Professor Paul Camic, Salomons Centre for Applied Psychology (Research Director) on **03330 117 114** or paul.camic@canterbury.ac.uk.

What will happen if I don't want to carry on with the study?
If you decide to take part in the study, you are free to withdraw at any time without having to give a reason, following which we will extract and destroy all your data.

Will my information be kept confidential?
All data and personal information will be stored securely in accordance with the Data Protection Act 1998. To maintain confidentiality, direct personal identifiers will be kept separately from other information, including experiment data. When the study is completed, all direct identifiers will be destroyed and only fully anonymised data will be stored within CCCU - in line with the Data Protection Act 1998 and the University's own data protection requirement - for up to 10 years, following which it will be destroyed. If you decide to take part I will ask for the name and contact details of your registered General Practitioner (GP). In the unlikely event that I have significant concerns for your well-being during the study, I will inform your GP, however this would be discussed with you beforehand. Confidentiality cannot be guaranteed if I have concerns that you or someone else might be at risk of harm.

Who has reviewed this study?
NHS research is monitored by an independent group of people, called a Research Ethics Committee, to protect your interests. This study has been reviewed and given favourable opinion by Dulwich - London Research Ethics Committee.

<u>What next?</u>

If you would like to participate within the study, or have any questions or concerns about the investigation, please contact me, Isaac Akande, by mobile number: 07498769752, or by email at: i.o.akande66@canterbury.ac.uk

You can also contact my supervisors, Dr Edyta Monika Hunter by telephone on: **0333 011 7070** and Dr Lucie Goddard on [redacted] For advice on whether you should or should not participate, I will recommend you seek guidance from the person you may have nominated (friend, family or professional) for support during the study.

Thank you for your time and interest.

Version 1.1
Date: 16th January 2016

SECTION C

Appendix D: Study consent form (stroke sample)

Centre Number:

Participant Identification Number for this trial:

CONSENT FORM

Title of Project: **Do Executive Functions Partially Underlie Theory of Mind in Adults?**

Name of Researcher: **Isaac Akande**

Please initial box

1. I confirm that I have read the information sheet dated .... (version............) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐
3. I understand that following anonymisation, data collected during the study may be looked at by others within the research team. ☐
4. I understand that relevant sections of my medical notes will be looked at by the researcher or [redacted] Trust clinicians involved in my care, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records for this purpose. ☐
5. I agree to take part in the above study. ☐

________________	________________	________________
Name of Participant	Date	Signature
________________	________________	________________
Name of Person taking consent	Date	Signature

Version 1.2

Date: 1st March 2016

SECTION C

Appendix E: Study consent form (healthy control sample)

Canterbury Christ Church University

Centre Number:

Participant Identification Number for this trial:

CONSENT FORM

Title of Project: **Do Executive Functions Partially Underlie Theory of Mind in Adults?**

Name of Researcher: **Isaac Akande**

Please initial box

1. I confirm that I have read the information sheet dated.................... (version............) for the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐

3. I understand that following anonymisation, data collected during the study may be looked at by others within the research team. ☐

4. I agree to take part in the above study. ☐

____________________	____________________	____________________
Name of Participant	Date	Signature
____________________	____________________	____________________
Name of Person taking consent	Date	Signature

Version 1.0

Date: 1st March 2016

Appendix F: Stroke data accessed from medical records

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Appendix G: Stimuli for the modified Information Processing A task (Vlaar & Wade, 2003)

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Appendix H: Word definition list for Cambridge Mindreading Face-Voice Battery (Golan et al., 2006)

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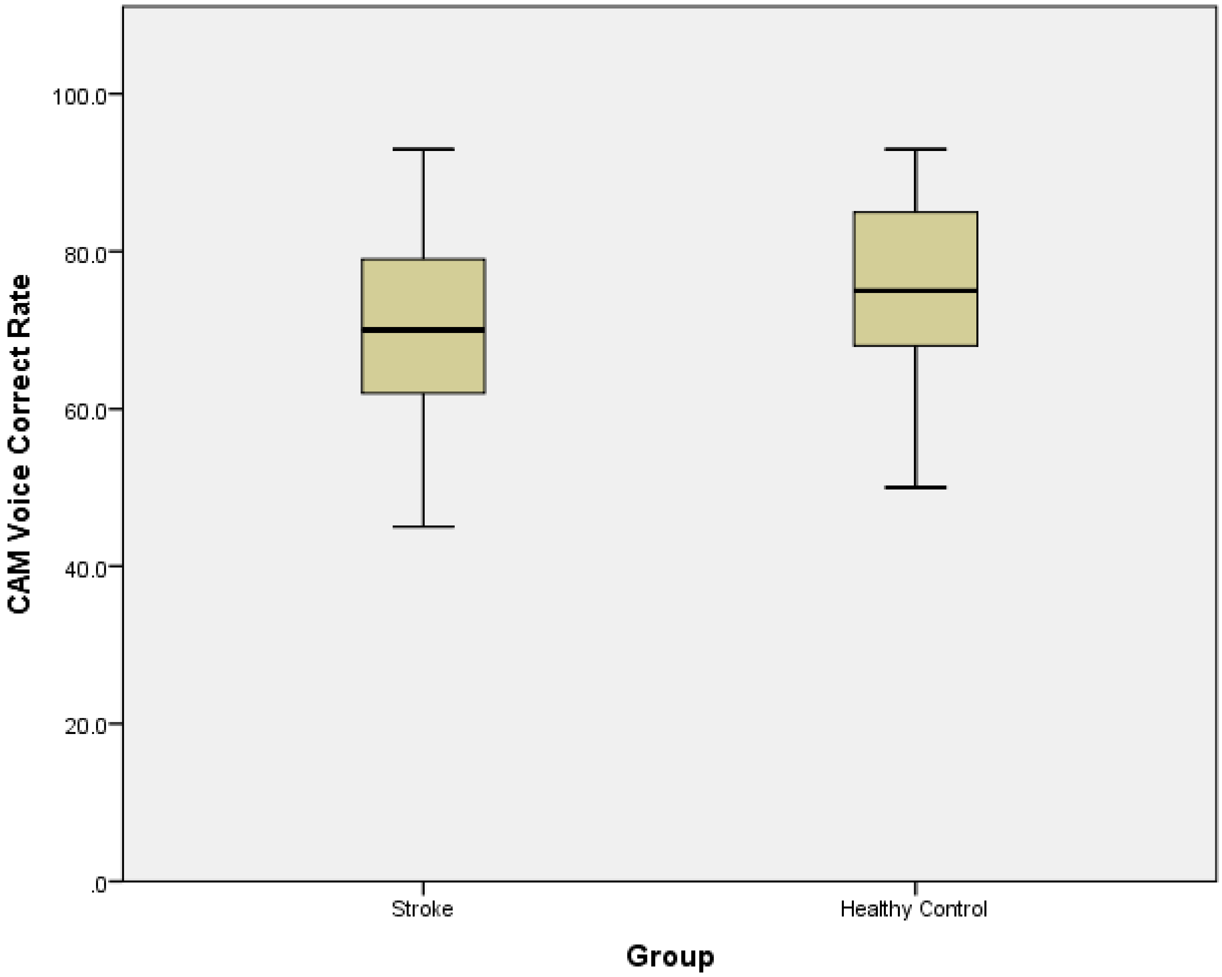
Appendix I: Analyses to test parametric assumptions of the variables (between-group comparisons)



Tests of Normality

Group		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	Df	Sig.
Stroke	CAM Voice Correct Rate	.132	22	.200*	.982	22	.943
Healthy Control	CAM Voice Correct Rate	.163	20	.172	.958	20	.510

*. This is a lower bound of the true significance.

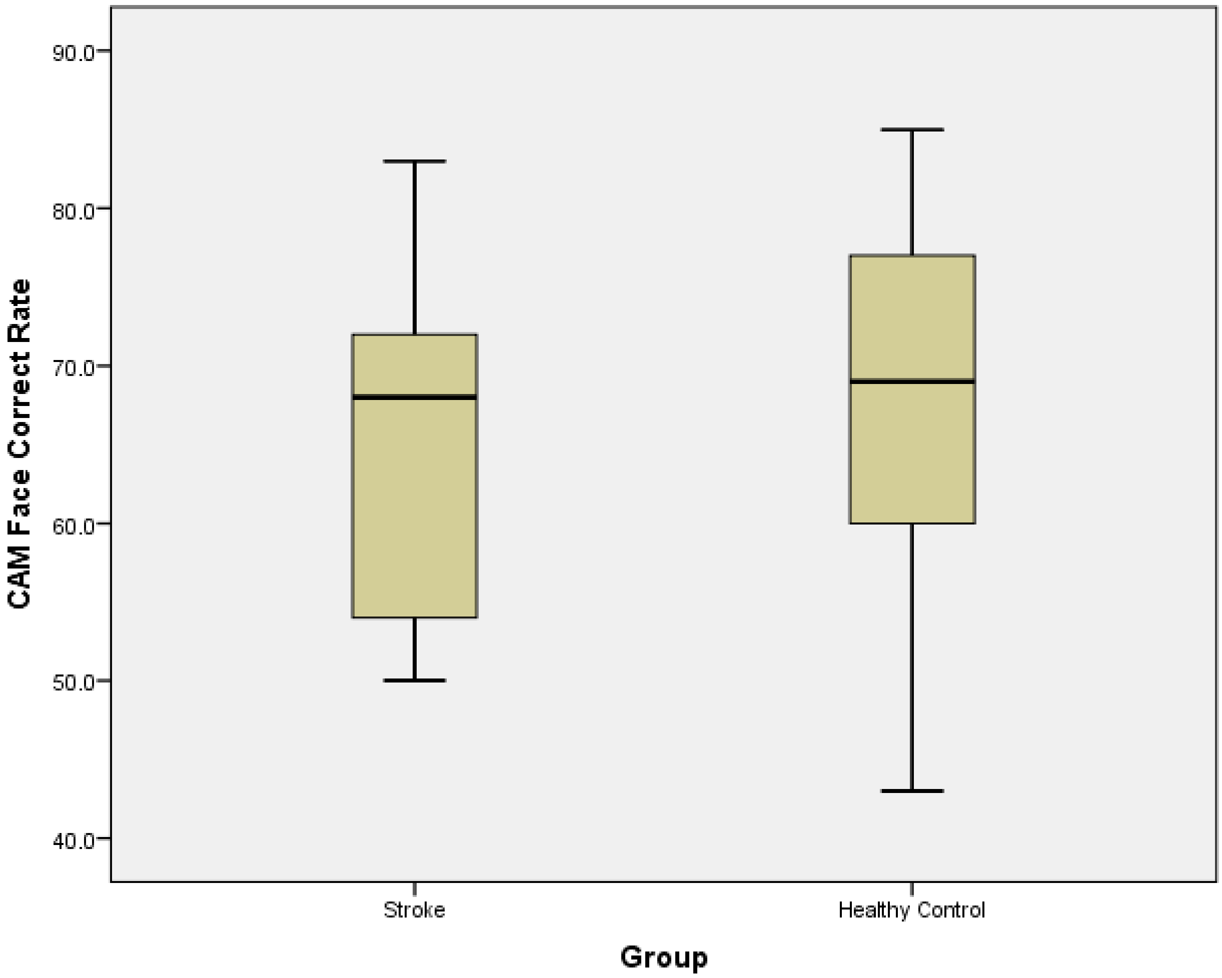
a. Lilliefors Significance Correction

Test of Homogeneity of Variances

CAM Voice Correct Rate

Levene Statistic	df1	df2	Sig.
.025	1	40	.875

SECTION C



Tests of Normality

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
CAM Face Correct Rate	Stroke	.139	22	.200*	.921	22	.080
	Healthy Control	.148	20	.200*	.958	20	.510

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

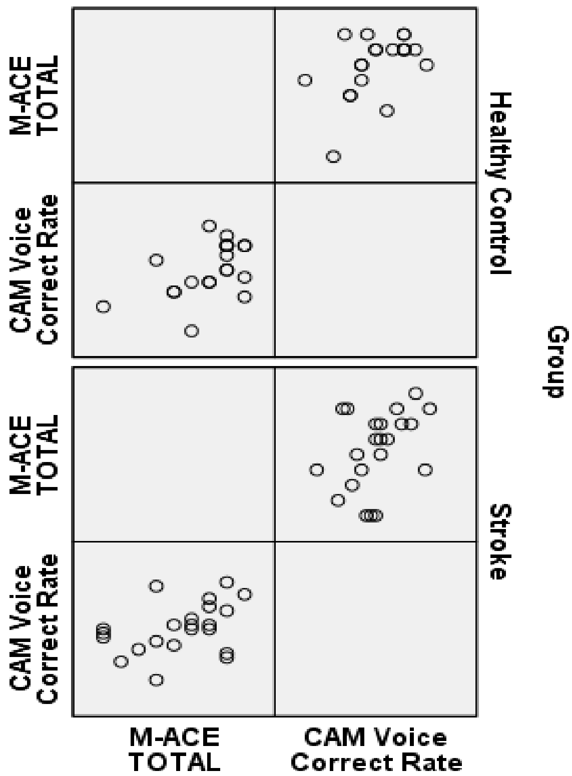
Test of Homogeneity of Variances

CAM Face Correct Rate

Levene Statistic	df1	df2	Sig.
.000	1	40	.990

SECTION C

Appendix J: Analyses to test the assumptions for ANCOVA (between-group comparisons)



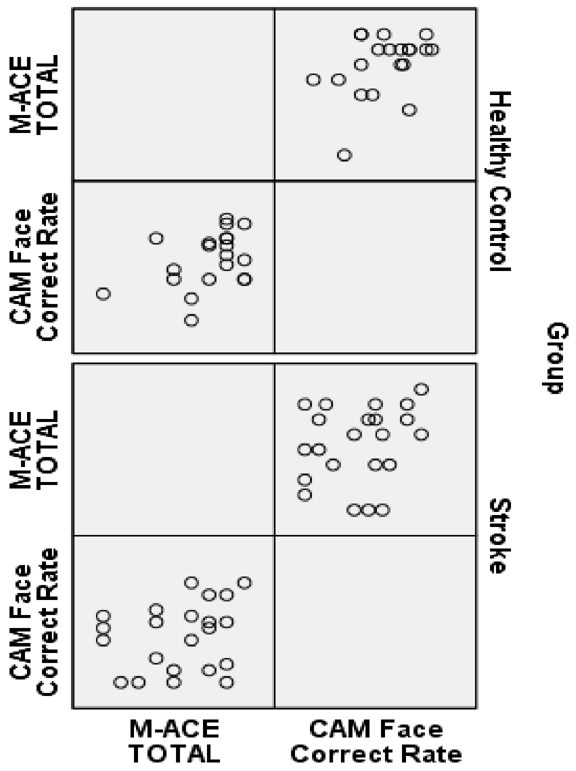
Tests of Between-Subjects Effects

Dependent Variable: CAM Voice Correct Rate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	1221.399[a]	2	610.699	5.332	.009	.215
Intercept	60.528	1	60.528	.528	.472	.013
Group * MACETOTAL	1221.399	2	610.699	5.332	.009	.215
Error	4466.721	39	114.531			
Total	227903.000	42				
Corrected Total	5688.119	41				

a. R Squared = .215 (Adjusted R Squared = .174)

SECTION C



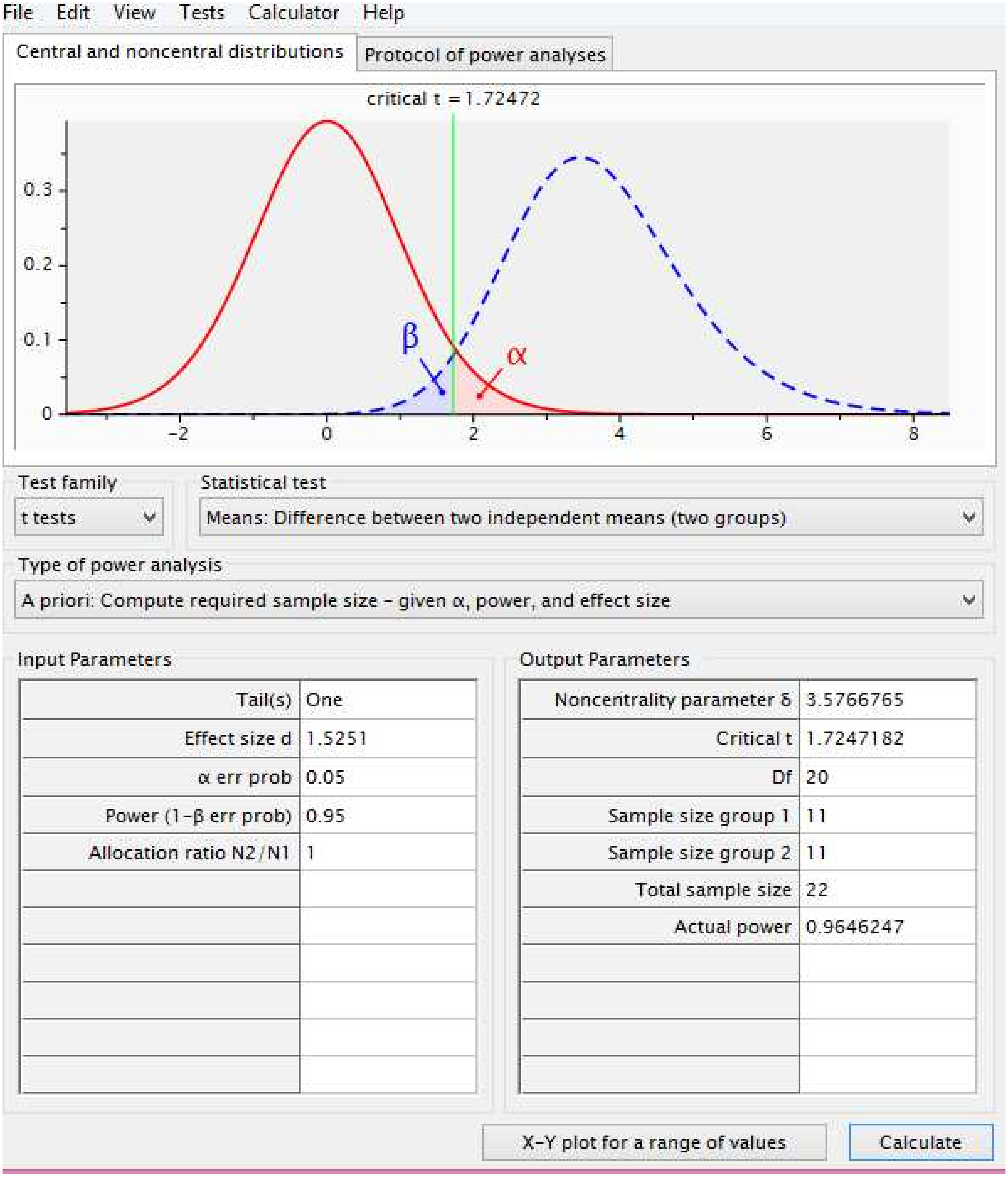
Tests of Between-Subjects Effects

Dependent Variable: CAM Face Correct Rate

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	531.630[a]	2	265.815	2.259	.118	.104
Intercept	216.971	1	216.971	1.844	.182	.045
Group * MACETOTAL	531.630	2	265.815	2.259	.118	.104
Error	4589.703	39	117.685			
Total	191788.000	42				
Corrected Total	5121.333	41				

a. R Squared = .104 (Adjusted R Squared = .058)

Appendix K: Raw a priori power calculations (between-group comparisons)



Appendix L: Approval letter from Research Ethics Committee

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Appendix M: Site-specific permission for NHS Trust A

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Appendix N: Site-specific permission for NHS Trust B

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Appendix O: Letter of Access for NHS Trust A

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Appendix P: Letter of Access for NHS Trust B

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Appendix Q: End of study form to the Research Ethics Committee

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Appendix R: End of study report to the Research Ethics Committee and NHS Trust R&D departments

DO EXECUTIVE FUNCTIONS PARTIALLY UNDERLIE THEORY OF MIND IN ADULTS?

Due to the poor convergent validity of the novel executive processes (Inhibition, Shifting, and Updating) tasks administered within the study, this aspect of the project was omitted. It was expected that these novel executive function tasks would be positively correlated with the established, DEX questionnaire (Wilson, Evans, Emslie, Alderman, & Burgess, 1998), however this was not the case (i.e., non-significant correlations were revealed). As such, the primary objective of exploring whether possible theory of mind deficits in stroke populations could be partially explained by executive dysfunction, could not be fulfilled.

Background

Theory of mind (ToM) refers to one's capacity to infer the mental states of self and other people and subsequently use these generated mental representations to evaluate, explain and anticipate consequential actions (Brownell, Griffin, Winner, Friedman, & Happe, 2000). Tager-Flusberg and Sullivan (2000) argued that there are two components within ToM, namely, social-cognitive and social-perceptual abilities. They proposed that the social-cognitive aspect of ToM fits with traditional definitions of ToM as a representational system, whereas the social-perceptual component is involved in the on-line interpretation of readily accessible verbal (e.g., speech content, tone) and non-verbal information (e.g., facial expression, body language, actions).

Objectives

The project focused on the secondary aims, which were concerned with the utility of a relatively novel and ecologically-valid measure of social-perceptual ToM, the Cambridge Mindreading Face-Voice Battery (CAM) (Golan, Baron-Cohen, & Hill, 2006). It consists of two separate tasks that evaluate the recognition of 20 different complex emotion and mental state concepts from visual (face) or verbal (voice) cues. These tasks were presented via laptop computer and ran on DMDX experimental software (Forster & Forster, 2003).

It was predicted that people who have had stroke would perform poorer than age- and education- matched healthy controls on the CAM Face and Voice tasks and that these groups could be distinguished solely on the basis of their performance on these ToM tasks.

Findings

There were non-significant differences between the CAM performances of 22 stroke survivors and 20 age- and education-matched healthy control participants. As expected, considering the aforementioned findings, the CAM was unable to accurately distinguish between the stroke and healthy control samples.

An exploratory cluster analysis conducted within the study revealed differential patterns of ToM impairment and preservation within the sample of stroke survivors (some stroke survivors performed poorer than healthy controls on the verbal ToM task, but not the visual ToM task; some stroke survivors performed poorer than healthy controls on both the verbal and visual ToM, etc.).

Implications

The results suggest that some of the social-perceptual ToM impairments observed in previous neuropsychological studies involving heterogeneous stroke sample (i.e., stroke group involving people with a diverse range of brain lesions) and people with other types of acquired brain injury (e.g., traumatic brain injury) might be attributable to the absence of cues reflective of real-world interactions (e.g., motion, voice intonation) in the artificial social-perceptual tasks that are widely administered.

The exploratory cluster analysis points towards a functional fractionation of social-perceptual ToM abilities, which appear to be dependent on the nature of the perceptual cues available to a person (face/visual vs. voice/auditory). Although, given exploratory nature of these findings, its support for the controversial fractionation hypothesis is tentative, and will need further investigation within lesion studies with greater experimental power combined with neuroimaging technology.

Arrangements for publication and dissemination

An article based on the project will be submitted to a peer-reviewed journal (viz., Neuropsychologia) following my viva voce for my thesis – and once corrections from the viva are completed - in June 2017. The project and findings will be presented within a [redacted] Research Event held within [redacted] in May 2017. Furthermore, the project will be presented to the Community Neurorehabilitation and [redacted] Care Teams within [redacted] and the [redacted] Service within [redacted]

[redacted] between May and August 2017. Participants will be sent addressed letters and/or emails informing them of the study findings following my viva in June 2017.

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Yours sincerely,

Isaac Akande (*Supervised by Dr Edyta Monika Hunter and Dr Lucie Goddard*)

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Appendix S: Research Feedback Letter for Participants

Research Project: Do Executive Functions Partially Underlie Theory of Mind in Adults?

Research Feedback Letter for Participants

Dear …………………………………………………,

Thank you for participating in my research project about the ability to guess what other people are thinking and feeling (also known as 'Theory of Mind').

I am writing this letter as a reminder of what we did together and to feedback what we found out from the research project.

The project intended to find out whether difficulties with Theory of Mind abilities might be linked to general difficulties with problem-solving. However, the computer tasks we developed to test problem-solving did not measure it accurately, so we focused on whether people that have had a stroke performed differently to people who have not had a stroke on Theory of Mind tasks. We measured Theory of Mind using a relatively realistic task (called the Cambridge Mindreading Face-Voice Battery) that required you to guess what actors were thinking or feeling based on a short voice or video clip:

A comparison showed that people that have had a stroke generally performed just as well as people that have not had a stroke on the Mindreading Battery. Some previous research studies suggest that Theory of Mind is affected by stroke and other types of acquired brain injury, whereas there are some studies that suggest this might only be the case for people that have had certain types of stroke. Given our findings, we think that some of the previous research that has looked at Theory of Mind, has used tasks which are very reliant on other thinking skills that are more commonly affected by stroke (e.g., memory or language). We think that the demands these tasks place on the other thinking skills might explain why some research has found people with stroke generally perform less well on Theory of Mind tasks, rather than there being specific difficulties in guessing what other people are thinking or feeling. I have suggested that further research is done to find out whether performance on realistic Theory of Mind tasks (like the one you completed) relates to real-world outcomes, like how comfortable a person is with managing social relationships.

However, looking further into our findings, we found that some people that have had a stroke found it easier to guess a person's thoughts and feelings from their voice, rather than from their face. We think this might mean that there are different networks in the brain that contribute to Theory of Mind. I have suggested that future research is completed to try to pinpoint the brain areas that form this network and determine what ways they might be contributing to Theory of Mind.

I have now written a report based on these findings, which will form part of my Doctorate in Clinical Psychology at Salomons, Canterbury Christ Church University. I will also be attempting to publish the report within an academic journal, which will contribute to what we know about brain functions and how best to assess these abilities for people who experience stroke.

Thank you very much for participating in my project and helping to further contribute to our understanding of Theory of Mind, I hope it was as pleasant an experience for you as it was for me.

If you have any further questions, please do contact me by email on: i.o.akande66@canterbury.ac.uk. Alternatively, you can leave a message for me on 0333 011 7070, and I will get back to you as soon as possible.

Yours sincerely,

Isaac Akande

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Kent, TN3 0TF

Appendix T: Guide for Authors Preparing for Manuscript Submission to Neuropsychologia

Preparation

The following article types are accepted:

(a) Research Reports
(up to 20 printed journal pages or about 17,000 words)

(b)Reviews and Perspectives
(up to 30 printed journal pages or 26,000 words). These should also provide critical accounts and comprehensive surveys of topics of major current interest within the scope of the journal.

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If your article includes any Videos and/or other Supplementary material, this should be included in your initial submission for peer review purposes.
Divide the article into clearly defined sections.

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Subdivision - numbered sections
Divide your article into clearly defined and numbered sections. Subsections should be numbered 1.1 (then 1.1.1, 1.1.2, ...), 1.2, etc. (the abstract is not included in section numbering). Use this numbering also for internal cross-referencing: do not just refer to 'the text'. Any subsection may be given a brief heading. Each heading should appear on its own separate line.

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State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

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Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

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Results should be clear and concise.

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If there is more than one appendix, they should be identified as A, B, etc. Formulae and equations in appendices should be given separate numbering: Eq. (A.1), Eq. (A.2), etc.; in a subsequent appendix, Eq. (B.1) and so on. Similarly for tables and figures: Table A.1; Fig. A.1, etc.

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