



LITERATURE REIVIEW: Metacognition in Children with Autistic Spectrum Disorder: A Systematic Review

EMPIRICAL PAPER: Metacognition in Children: How do the emergent awareness abilities of prediction, error detection and evaluation change by age?

Submitted by Rebecca Tegen Jenkin, to the University of Exeter
as a thesis for the degree of Doctor of Clinical Psychology, May 2019

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METACOGNITION IN CHILDREN

Table of Contents

Table of Contents	2
List of Tables	6
List of Figures	7
LITERATURE REVIEW	8
Abstract	9
Introduction	10
Methods	14
Search Strategy	14
Search Terms	15
Eligibility Criteria	16
Evaluation Criteria	17
Results	17
Critical Summary	26
Predictive Emergent Awareness	27
Evaluative Emergent Awareness	29
Discussion	31
Clinical Implications	33
Limitations	34
Future Research	34
Conclusion	35

METACOGNITION IN CHILDREN

References	36
Appendix A – Quality Assessment Tool for Quantitative Studies	44
Appendix B - Preparation and Submission Requirements for the <i>Journal of Autism and Developmental Disorders</i>	52
EMPIRICAL PAPER	54
Abstract	55
Introduction	57
Research Questions and Hypotheses	60
Method	61
Participants	61
Power Analyses	62
Design	62
Materials	62
The Junior Metacognitive Assessment Inventory	62
The Dual-task Attention to Response Task	63
Judgment of Confidence Task	65
Procedure	66
Proposed Data Analysis Strategy	68
How do children’s emergent awareness abilities of prediction, error detection and evaluation differ between younger and older children?	68
Is there a relationship between prediction, error detection and evaluation? Does this differ between younger and older children?	70

METACOGNITION IN CHILDREN

How does children's subjective metacognitive knowledge differ in younger and older children? How do children's emergent awareness abilities relate to their subjective metacognitive knowledge in these age groups?	70
Results	71
How do children's emergent awareness abilities of prediction, error detection and evaluation differ between younger and older children?	71
Error Detection	71
Prediction	72
Evaluation	72
Is there a relationship between prediction, error detection and evaluation? Does this differ between younger and older children?	74
How does children's subjective metacognitive knowledge differ in younger and older children? How do children's emergent awareness abilities relate to their subjective metacognitive knowledge in these age groups?	77
Discussion	78
Clinical Implications	82
Strengths and Limitations	83
Future Research	85
Conclusion	85
References	87
Appendix A: The Metacognitive Assessment Inventories (Version A & B)	94
Appendix B: Judgment of Confidence Task	95

METACOGNITION IN CHILDREN

Appendix C: Ethics Approval Letter	97
Appendix D: Information Leaflet for Schools	99
Appendix E: Headteacher and Teacher Consent Forms	101
Appendix F: Information Leaflet and Consent Form for Parents/Carers	103
Appendix G: Child Information Sheet, Consent Form and Debrief Sheet	106
Appendix H: Missing Data for JOC Questions	109
Appendix I: Outlier Analysis	110
Appendix J: Dissemination Statement	111
Appendix K: Preparation and Submission Requirements for Consciousness and Cognition	112

List of Tables**Literature Review**

Table 1. Search Terms used in the Literature Review.

Table 2. Inclusion and Exclusion Criteria used for the Literature Review.

Table 3. Summary of Eligible Studies from the Literature Search Strategy and Eligibility Screening.

Empirical paper

Table 1. Means and standard deviations of the error detection, prediction, and evaluation scores by age group.

Table 2. Correlations among prediction, error detection, evaluation, and metacognitive knowledge by age.

Table 3. Means and standard deviations of the subjective metacognitive knowledge scores by age group.

Table A1. The number (N) of missing data points for each of the Judgment Of Confidence (JOC) questions.

Table A2. Correlations among prediction, error detection, evaluation, and metacognitive knowledge by age with outliers removed.

List of Figures**Literature Review**

Figure 1. Krasny-Pacini et al.'s (2015) model of online/emergent awareness, which breaks this down into offline and 'true' online awareness.

Figure 2. Results of the Literature Search Strategy and Eligibility Screening.

Empirical Study

Figure 1. Flowchart showing recruitment of participants

**SCHOOL OF PSYCHOLOGY****DOCTORATE IN CLINICAL PSYCHOLOGY****LITERATURE REVIEW****Metacognition in Children with Autistic Spectrum Disorder: A Systematic
Review**

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Abstract

Objective: Children with Autistic Spectrum Disorder (ASD) may struggle with their metacognition due to having poor theory of mind; i.e., their lack of awareness of how others are feeling may also mean they lack self-awareness of their own cognitive strengths and weaknesses. This systematic review collated research that investigated metacognitive skills of emergent awareness (specifically prediction, error detection, and evaluation of own performance on a task) in children with and without ASD. The review addressed the question: do children with ASD have diminished emergent awareness compared to neuro-typical children?

Method: Systematic searches were conducted in PsycINFO, Ovid Medline, EMBASE, Cochrane library, and Web of Science databases with specific search terms. Studies were published before December 2018. A total of 1,247 records were identified, which reduced to 620 once duplicates were removed. Screening these by title and abstract resulted in 24 full-text articles being assessed for eligibility. Fourteen were excluded and so ten articles were included in the review.

Results: No included articles explored the emergent awareness ability of error detection in children with ASD. The studies suggested children with ASD did not have diminished prediction ability compared to those without ASD, but results were more mixed for the emergent awareness skill of evaluation.

Conclusions: Not all components of emergent awareness appear to be diminished in children with ASD compared to typically developing children. Further research is required to address limitations of the lack of valid and reliable measures and experimenter blinding.

Keywords: autistic spectrum disorder, children, metacognition, systematic review

Introduction

Autistic spectrum disorder (ASD) is a neurodevelopmental disorder characterised by: repetitive or restrictive patterns of behaviour, interests or activities; deficits in social communication; and deficits in social interaction (American Psychiatric Association, 2013). This means that individuals with ASD often struggle to develop, maintain, and understand relationships (Travis & Sigman, 1998). A well-known theory states that this is due to a cognitive deficit that inhibits the development of 'theory of mind' in children with ASD (Baron-Cohen, Leslie, & Frith, 1985; Baron-Cohen, 2000). This is the ability to assign mental states (such as beliefs and intentions) to other people, consequently allowing individuals to explain and predict others' behaviours (Premack & Woodruff, 1978). In neuro-typical children theory of mind tends to develop around three to five years of age (Wellman, Cross, & Watson, 2001). On the other hand research has found that those with ASD do not appear to develop theory of mind in childhood (Happé, 1994; Mazza et al., 2017), or it is slower to develop in this population (Pino et al., 2017).

It has been put forward that recognising mental states in *others* relies on the same underlying cognitive mechanism needed to recognise them in *ourselves* (Frith & Happé, 1999). Frith and Happé (1999) argue that people who cannot pass theory of mind tests may also be unable to understand their own mental states. They theorise that this would mean that individuals with ASD have limited self-awareness: the understanding that you are an individual with your own thoughts, feelings and beliefs. The only way these individuals can do so is by gaining an explicit self-awareness through effortful learning, developing an explicit knowledge of their cognitive strengths and weaknesses, which is often only achieved by those with high-functioning ASD later in their life (Frith &

METACOGNITION IN CHILDREN

Happé, 1999). This deficit in self-awareness in those with ASD (Williams, 2010) suggests that their metacognition could also be impaired (Carruthers, 2009).

Metacognition, thinking about thinking, is our ability to think about our own cognitive processes (Flavell, 1979). It encompasses both an individual's metacognitive knowledge and metacognitive skills (Veenman, Van Hout-Wolters & Afflerbach, 2006). Metacognitive knowledge is a person's learning and beliefs about what affects their thinking ability (Flavell, 1979). Examples of this include believing you learn information better by reading it rather than listening to it, and knowing that one strategy for learning information is the repetition of said information (Flavell, 1979). Metacognitive skills are the cognitive processes that an individual employs to monitor and regulate their actions, including their ability to predict, monitor and evaluate while carrying out a task (Krasny-Pacini et al., 2015).

Models of metacognition are often found in the adult brain injury literature (Fleming & Ownsworth, 2006), as components of an individual's metacognition have been linked to the success of rehabilitation (Ownsworth & Clare, 2006). One such model has been put forward by Toglia and Kirk (2000). The model differentiates between knowledge and beliefs that are pre-existing (in a person's long-term memory), and the knowledge and awareness that is activated when the same individual carries out a task. These two separate aspects, termed metacognitive knowledge and *online awareness* in the model, dynamically interact with each other as a task is carried out.

Krasny-Pacini et al. (2015) further extended Toglia and Kirk's (2000) concept of *online awareness* to include two separate components, termed *offline awareness* and *online awareness*. These two components were labelled collectively as online/emergent awareness. This can be seen in Figure 1. Offline

METACOGNITION IN CHILDREN

awareness was defined as an individual's ability to predict and evaluate in relation to a task they are carrying out, which happens immediately *before and after* a task. Although offline awareness is activated within the context of the task it does not happen while the task is actually being carried out (Krasny-Pacini et al., 2015). In this paper these emergent awareness skills are referred to as predictive and evaluative emergent awareness. On the other hand, Krasny-Pacini et al. (2015) termed 'true' online awareness as the monitoring of performance and error detection that happens *during* a task. In this paper this is known as error detecting emergent awareness.

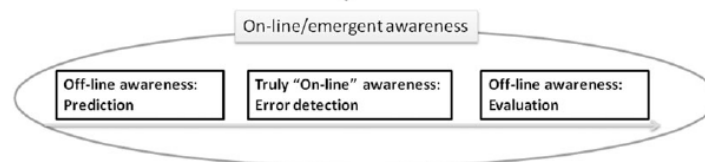


Figure 1. Krasny-Pacini et al.'s (2015) model of online/emergent awareness, which breaks this down into offline and 'true' online awareness.

The literature often refers to emergent awareness as individuals' metacognitive skills. In adults, higher abilities in metacognitive skills/emergent awareness have been linked to better outcomes after traumatic brain injury (Ownsworth & Fleming, 2005) and lower depressive symptoms (Slife & Weaver, 1992). Research suggests that in children this ability is a strong predictor of learning performance (Veenman & Spaans, 2005), in that those with greater emergent awareness usually have higher academic achievement (Freeman, Karayanidis, & Chalmers, 2017). There may also be a link between this ability and anxiety in children, as findings suggest that those with anxiety disorders are less confident in their metacognitive skills (Alfano, Beidel, & Turner, 2006; Ellis & Hudson, 2010; Smith & Hudson, 2013). Overall these findings suggest that

METACOGNITION IN CHILDREN

emergent awareness may have an influence on learning and on mental health difficulties.

It has been found that children with ASD have difficulties with school and anxiety (Eaves & Ho, 1997; Gillott, Furniss, & Walter, 2001; Kuusikko et al., 2008), perhaps lending support to the theory that metacognition is impaired in individuals with ASD (Carruthers, 2009). From a preliminary search of the literature it appears that studies looking at metacognition in children with ASD have found mixed results as to whether these children have reduced emergent awareness or not (Elmose & Happé, 2014; Grainger, Williams, & Lind, 2016b; McMahon, Henderson, Newell, Jaime, & Mundy, 2016; Wilkinson, Best, Minshew, & Strauss, 2010; Wojcik, Allen, Brown & Souchay, 2011). Most of these studies appear to explore the predictive or evaluative emergent awareness.

In terms of error detecting emergent awareness, a recent systematic review collated the evidence that explored this in children and adults with ASD using Event-Related Potentials (ERP) measures (Hüpen, Groen, Gaastra, Tucha, & Tucha, 2016). Their finding suggested there was some evidence that those with ASD had reduced error detection ability, when comparing those with ASD to neurotypical controls (Hüpen et al., 2016). However, there is varying evidence of whether ERP measures are able to capture explicit awareness of error detection, or if they are also capturing errors that individuals are unaware of too (Hester, Foxe, Molholm, Shpaner, & Garavan, 2005; Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001). As metacognition is defined as our ability to *consciously* think about our cognitive processes (Hacker, 1998), it could be argued that ERP measures may not be an accurate method for measuring this.

METACOGNITION IN CHILDREN

To date there has been no review collating evidence to determine if conclusions can be drawn about the overall emergent awareness skills in individuals with ASD, specifically children. Therefore, the aim of this literature review was to explore the research question: *do children with ASD have diminished emergent awareness compared to neuro-typical children?* The definition of emergent awareness was taken from the model put forward by Krasny-Pacini et al. (2015), which encompasses the skills of prediction, error detection, and evaluation. Due to the finding that ERP measures may be measuring errors that participants are unaware of (Hester et al., 2005; Nieuwenhuis et al., 2001), it was decided to exclude studies that measured error-detection in this way.

Methods

Search Strategy

Systematic searches were conducted in the following electronic databases: PsycINFO, Ovid Medline, EMBASE, Cochrane library, and Web of Science. There was no restriction on publication date and searches were completed in December 2018. Reference lists of included studies were scrutinized, and citation searches were undertaken on included studies for relevant citations. Search criteria were reviewed to ensure these would be captured. Grey literature was not used due to time and resource limitations.

The 2015 PRISMA (Preferred reporting items for systematic review and meta-analysis) protocol was followed (Moher et al., 2015) to identify and screen records. Records were firstly identified through database searching within the title and abstract fields. An initial screening took place using the inclusion and exclusion criteria. The full-text articles were then assessed for eligibility. At this stage a second researcher reviewed and rated six studies. The second

METACOGNITION IN CHILDREN

researcher made an independent yes/no decision as to whether the study should be included or excluded from the review based on the inclusion and exclusion criteria and these decisions were discussed with the main reviewer. If inter-rater reliability was low then the inclusion and exclusion criteria were reviewed and changed, until the raters were in agreement.

Search Terms

Search terms were generated from looking at research papers' keywords in the preliminary search of the literature, from speaking to an author in the field, and searching for concepts in databases and scanning for alternative words and phrases. The search terms used in relation to the research question can be seen in Table 1. These are presented by construct. Truncations were used where the stem word may have different endings, for example, "autis*" would retrieve "autism" and "autistic".

Table 1

Search Terms used in the Literature Review

Construct	Search terms
Emergent awareness	("monitoring impairment" OR "error correction" OR "error monitoring" OR metacognit* OR "emergent awareness" OR "emergent self awareness" OR "cognitive regulation" OR introspection OR metamem* OR "memory awareness" OR "online awareness" OR "on task awareness" OR "error detection" OR mentalising OR "action memory" OR "judg* of confidence" OR "emergent self-awareness" OR "on-task awareness" OR "self performance" OR self-performance OR "self evaluat*" OR self-evaluat* OR "self understanding" OR self-understanding OR "self concept" OR self-concept OR "self awareness" OR self-awareness OR "self monitoring" OR self-monitoring OR "self perception" OR self-perception) AND
Autistic Spectrum Disorder	(Autis* OR Asperger* OR ASD OR ASC OR "Neurodevelopmental disorder*") AND
Age group	(child OR child* OR boy OR girl OR adolesce* OR teen* OR youth OR young* OR pupil OR student OR paediatric)

METACOGNITION IN CHILDREN

Eligibility Criteria

The inclusion and exclusion criteria were outlined using the Population, Intervention, Comparator, Outcome, Study design (PICOS) criteria (Centre for Reviews and Dissemination, 2006) and are shown in Table 2.

Table 2

Inclusion and Exclusion Criteria used for the Literature Review

Inclusion	Exclusion
<i>Population</i>	
<ul style="list-style-type: none"> Children and adolescents between the ages of three and eighteen years old. Studies including both children and adults if the child data was analysed and evaluated separately. 	<ul style="list-style-type: none"> Non-human subjects.
<i>Exposure</i>	
<ul style="list-style-type: none"> A formal diagnosis of Autistic Spectrum Disorder¹ (ASD; including those with sub-types of ASD) by a trained professional such as psychiatrist or psychologist. 	<ul style="list-style-type: none"> Children and adolescents with traumatic brain injury, neurodevelopmental disorders other than ASD, or learning disabilities (unless as an additional and separate comparator group).
<i>Comparator</i>	
<ul style="list-style-type: none"> Typically developing/neurotypical children or adolescents (without a diagnosis of ASD). The population at different time points. 	<ul style="list-style-type: none"> No comparator controls used. Those with learning disabilities or neurodevelopmental disorders as the only comparator group (allowed where also a typically developing/neurotypical group). Adults.
<i>Outcome</i>	
<ul style="list-style-type: none"> At least one measure of emergent awareness/metacognitive skills (an individual's ability to monitor and control their own cognitive processes; including their ability to predict, plan, monitor and evaluate while carrying out a task) that is self-reported. Behavioural task, which can be objectively measured in terms of success/failure, alongside the metacognitive element. 	<ul style="list-style-type: none"> Measures of broad self-awareness (conscious knowledge of the self), mentalising (how we think about ourselves), or metacognitive knowledge (an individual's knowledge and beliefs about what affects their thinking ability) not in relation to metacognitive skills. Measures of metacognitive skills that are not self-report, for example, teacher or parent report. Error-related potential studies.
<i>Study Design</i>	
<ul style="list-style-type: none"> Quasi-experimental designs. 	<ul style="list-style-type: none"> Qualitative studies.

METACOGNITION IN CHILDREN

- Longitudinal cohort studies.
 - Case studies.
 - Case series.
 - Studies published after 2018.
 - Non-English articles.
-

Note: ¹as defined by the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 2013) or the International Classification of Disease (World Health Organisation, 1992).

Evaluation Criteria

Articles were evaluated using the Effective Public Health Practice Project (EPHPP) Quality Assessment Tool for Quantitative Studies (QATQS; see Appendix A; EPHPP, 1998; Thomas, Ciliska, Dobbins, & Micucci, 2004). This tool can be used to evaluate a range of different study designs, assessing study quality on aspects such as confounders, blinding and data collection methods. A second researcher assessed three studies included in the review, using the QATQS measure. The QATQS has been found to have good inter-rater reliability (Armijo-Olivo, Stiles, Hagen, Biondo, & Cummings, 2012).

Results

A total of 1,247 articles were derived from the search terms across the identified databases, reference lists and citation searches of the included papers. After duplicates had been deleted, 620 title and abstracts were screened against the inclusion and exclusion criteria. Of these, 596 did not meet the specified PICOS criteria. Therefore, a total of 24 full-text records were assessed for eligibility based on specified inclusion and exclusion criteria. A second researcher reviewed and rated six studies (100% inter-rater reliability). Fourteen articles were screened out and ten articles were included. Reasons for exclusion are provided in Figure 2. Reference lists of the 10 full-text papers were reviewed for relevant records and no additional publications were identified. The 10 records were evaluated using the QATQS measure. An independent reviewer completed the QATQS for three included records (100%

METACOGNITION IN CHILDREN

inter-rater reliability). All included studies used quasi-experimental designs, comparing typically developing participants with those with ASD.

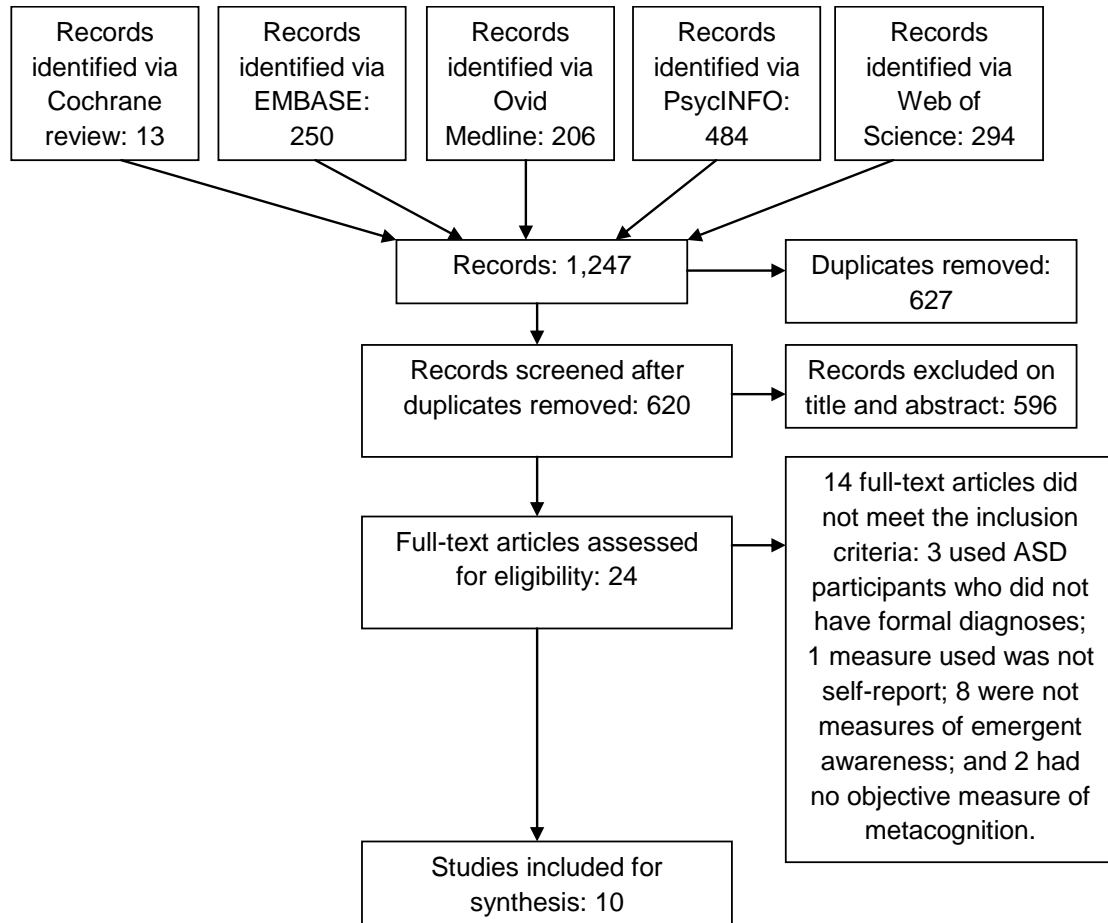


Figure 2. Results of the Literature Search Strategy and Eligibility Screening.

METACOGNITION IN CHILDREN

Table 3

Summary of Eligible Studies from the Literature Search Strategy and Eligibility Screening.

Author	Sample	Measures	Results and Conclusion	Evaluation	QATQS
Brosnan et al. (2016)	26 participants with ASD (21 males; age $M = 13.7$ years, $SD = 1.3$) vs 56 TD participants (16 males; age $M = 10.5$ years, $SD = 0.5$). ASD participants were matched with TD participants working at same mathematics level.	Participants were individually given 15 mathematics questions in sets of five. The first five questions were always level one and then became more difficult (level two, level three) depending on if participants made errors or not. After each question participants were asked whether they thought they had got the answer correct or not (possible answers: right, wrong, don't know), to assess if they were aware when they had made errors.	The two groups did not differ significantly on the number of correct responses to the questions, $t(31.89) = 1.7$, <i>ns</i> . Participants with ASD reported more incorrect answers as correct, $t(60) = 1.81$, $p < .05$, $d = .53$. The authors put this forward as evidence that children with ASD are significantly worse at evaluating their answers compared to TD children, suggesting they have diminished evaluative emergent awareness.	Strengths: Age and IQ were included in the analysis and found not to be impacting the results. Limitations: matching of the samples, gender ratio differed between groups.	A - moderate B - moderate C - moderate D - weak E - weak F - N/A Global: Weak

METACOGNITION IN CHILDREN

Elmose & Happé (2014)	24 participants with ASD (age $M = 13.4$ years, $SD = 1.5$) vs 21 TD participants (age $M = 10.1$ years, $SD = 2.5$). All participants were male and matched on VMA.	Participants were individually given memory tasks where they had to remember sequences of pictures (2 trials = buildings, 2 trials = faces). There were PJA's (how many pictures they thought they would be able to place/have placed in the same order?) at three time points: before, after a distracter task and after participants had to recall the sequences A visual scale from 0 - 6 was shown to help them answer. Participants were also asked a JOC question at the end of the task (how sure they were of each of the pictures). The answers were totally sure, pretty sure, or unsure.	A repeated measures ANOVA showed a significant difference between PJA at the three time-points, $F(1.75) = 10.4$, $p < .001$, $\eta p^2 = .20$, but was non-significant for group effect. Chi-square analysis showed a trend that those with ASD had higher PJA on building trials and those without ASD had higher PJA on face trials ($p = .06$, $d = .60$). Another repeated measures ANOVA revealed differences between the trials for the JOC, $F(3) = 4.3$, $p = .006$, $\eta p^2 = .09$, but no effect of group. This suggests that children with ASD have similar predictive and evaluative emergent awareness as TD children.	Strengths: Participants were matched on VMA, task adapted from a previous one. Limitations: Small sample size, differences in ages between groups.	A - moderate B - moderate C - moderate D - weak E - weak F - N/A Global: Weak
Grainger, Williams & Lind (2016a). Exp 2.	22 participants with ASD (19 males; age $M = 13.70$ years, $SD = 1.45$) vs 21 TD participants (19 males; age $M = 13.21$ years, $SD = 1.18$). Participants were equated closely on VIQ, PIQ, FSIQ and chronological age.	Participants were shown two sets of 22 word pairs, each consisting of a cue word and a target word. Each pair was presented for 8 s each. Then they were presented with either the cue word alone (cue alone condition), or both the cue and targets words (cue-target condition), in a fixed random order and asked "will you remember the target word at a later point?" (JOL). Immediately afterwards they completed a cued-recall test where they were asked to recall the missing target word pair from each cue word.	There were no significant differences between groups in performance, in either the cue alone condition, $t(41) = 0.65$, $p = .517$, $d = .24$, or the cue-target condition, $t(41) = 0.33$, $p = .739$, $d = .14$. There were also no significant differences in JOL in the cue alone condition, $t(41) = 0.67$, $p = .505$, $d = .25$, and the cue-target condition, $t(41) = 0.56$, $p = .582$, $d = .19$, between participants with ASD and TD participants. These findings suggest children with ASD have similar predictive emergent awareness as TD children.	Strengths: task based on one used previously, participants were closely equated on IQ and age. Limitations: does not disclosure the recruitment procedure for participants with ASD, small sample size, low power.	A - moderate B - moderate C - strong D - weak E - weak F - N/A Global: Weak

METACOGNITION IN CHILDREN

Grainger, Williams & Lind (2016b)	32 participants with ASD (age $M = 13.59$ years, $SD = 1.36$) vs 30 TD participants (age $M = 13.27$ years, $SD = 1.06$). Gender ratio not reported. The groups were closely equated on age and verbal and non-verbal ability (using the WASI).	Participants watched an informative video and were then asked 16 questions about what they had seen. Afterwards answering the 16 questions they were given JOC questions for each one on a seven point Likert scale. They were asked to rate how confident they were in their answers (from <i>extremely unsure</i> to <i>extremely sure</i>). Finally, at a later point participants were given the opportunity to cross out any of their answers they believed were incorrect.	There were no significant differences between the amount of answers each group recalled, $t(60) = 0.57$, $p = .57$, $d = .13$. However, participants with ASD had significantly less accurate JOC scores than TD participants, $t(60) = 1.75$, $p = .043$, $d = .41$. They also relied on their JOC ratings less when deciding what answers to cross out, $t = 2.43$, $p = .018$, $d = .64$. These findings suggest children with ASD have diminished evaluative emergent awareness compared to TD children.	Strengths: larger sample size than other studies, participants were closely equated on IQ and age, task based on one previously used. Limitations: recruitment procedure not reported.	A - weak B - moderate C - weak D - weak E - weak F - N/A Global: Weak
Maras, Gamble, & Brosnan (2019; first published 2017).	40 participants with ASD (30 males; age $M = 13.33$ years, $SD = 1.25$) vs 95 TD participants (58 males; age $M = 13.40$ years, $SD = 1.15$). No differences in age across groups, however, participants with ASD were under-achieving in maths (stated this was reflective of the ASD population).	Participants took part in a computer programmed 'math challenge', where they were asked maths questions on a computer. This was a novel task created for the study. Afterwards participants completed a 5-point Likert scale JOC, from <i>I'm sure I got it right</i> to <i>I'm sure I got it wrong</i> . Half of the participants received feedback after each question (feedback condition), and the other half did not (no feedback condition). Participants were also asked intention questions before and after, which are not reported here.	A 2(Group) x 2 (Condition: Feedback vs No Feedback) x 2 (Answer: correct vs incorrect) mixed ANOVA explored if participants assigned higher confidence to correct rather than incorrect answers. This revealed a main effect of Group, $F(1, 120) = 4.15$, $p = .04$, $\eta p^2 = .03$: participants with ASD were significantly more confident that their answers were correct than the TD group. However, there was no group x answer interaction, $F(1, 120) = 0.59$, $p = .45$, $\eta p^2 = .005$, showing both groups had higher confidence for correct rather than incorrect answers. This suggests children with ASD have similar evaluative emergent awareness to TD children.	Strengths: good number of participants, ecologically valid measure. Limitations: groups were not IQ matched, maths ability was assessed by teachers before testing rather than as an independent measure, 'maths challenge' measure a novel task.	A - moderate B - moderate C - strong D - weak E - weak F - N/A Global: Weak

METACOGNITION IN CHILDREN

McMahon, Henderson, Newell, Jaime, & Mundy (2016).	28 participants with ASD (24 males; age $M = 13.47$ years, $SD = 2.79$) vs 31 TD participants (16 males; age $M = 14.56$ years, $SD = 1.61$). No significant differences between the groups on age, VIQ, PIQ, or gender distribution.	Participants were shown face stimuli that gradually appeared on screen and were asked to guess the emotion the face was displaying as quickly as possible. Every time they guessed they were also asked to give a JOC on a 5-point Likert scale from <i>very unconfident</i> to <i>very confident</i> . The face stimulus was then revealed in whole and participants were asked if they would like to change their affect answer and if they did, give another JOC rating.	Hierarchical linear modelling assessed whether metacognition was associated with performance. This revealed participants were more confident for correct affect selection, $t(48) = 7.07$, $p < .01$. Confidence was a stronger predictor of accuracy for TD participants than those with ASD, as there was an interaction between confidence and group, $t(48) = -3.46$, $p < .01$. TD participants had a stronger relationship between confidence and accuracy than participants with ASD, suggesting they had better evaluative emergent awareness.	Strengths: Hierarchical linear modelling allowed demographic factors to be included in the analysis. Limitations: unknown if the measure used was based on a previous study.	A - moderate B - moderate C - strong D - weak E - weak F - N/A Global: Weak
Williams, Bergström, & Grainger (2018). Exp 2.	11 participants with ASD (10 males; age $M = 9.86$ years, $SD = 1.69$) vs 11 TD participants (8 males; age $M = 9.86$ years, $SD = 1.00$). The groups did not differ significantly on age, VIQ or PIQ.	In an initial test phase, participants were asked 50 general knowledge questions on a computer and given an unlimited amount of time to provide an answer. If they were unsure of the answer they were told to guess. Once they had typed an answer they were asked to give a JOC using a sliding scale from 0 (not confident) to 100 (confident) for each question. Afterwards participants completed a re-test phase, where they were given a surprise re-test of answers they got incorrect. They did not provide JOC ratings during this phase.	A 2 (Group) x 2 (Test period: initial test/retest) revealed a main effect of group $F(1, 20) = 5.04$, $p = .04$, $\eta p^2 = .20$. TD participants performed better on the general knowledge questions than those with ASD. Participants with ASD had significantly less accurate JOC scores than TD participants, $t(20) = 2.00$, $p < .05$, $d = .86$. This suggests children with ASD have diminished evaluative emergent awareness when compared to TD children.	Strengths: sample was matched by age and IQ, questions used were age appropriate. Limitations: small sample size, novel task not used previously, TD participants performed significantly better on the task than those with ASD.	A - weak B - moderate C - weak D - weak E - weak F - N/A Global: Weak

METACOGNITION IN CHILDREN

Wojcik, Allen, Brown, & Souchay (2011)	16 participants with ASD (14 males; age $M = 11.55$ years, $SD = 2.06$) vs 16 TD participants (11 males; age $M = 10.95$ years, $SD = 3.0$). There were no differences on age and IQ across groups.	Instruction sequence-action task where participants were given sequences of instructions (between two & five in sequence length) to remember and carry out (e.g. (1) <i>pick up the red ruler</i> (2) <i>and put it in the blue box</i> . Five trials were carried out for each sequence length and after each they were asked to give a JOC (how well do you think you did in this task?) on a 10 point scale from 'I did not do very well' to 'I did very well'. Three encoding conditions were tested for each participant: instructions only; instructions read and acted by the experimenter; and read by the experimenter and acted by the participants.	A 2 (group) x 3 (condition) ANOVA revealed a main effect of group, $F(1, 30) = 8.29$, $p < .01$, $\eta p^2 = .22$ suggesting participants with ASD had poorer memory performance than TD participants. There were no significant differences in JOC's between the two groups, $F(1, 30) = 3.48$, $p = .072$, $\eta p^2 = .10$, or in the accuracy of the confidence judgments, $F(1, 30) = 1.74$, $p = .20$, $\eta p^2 = .05$. Participants with ASD made similar JOCs as the TD participants and were no less reliable in the accuracy of their judgments. These findings suggest children with ASD do not have diminished evaluative emergent awareness compared to TD children.	Strengths: the task used was based on a previous measure. Limitations: small sample size, TD participants performed significantly better on the task, unclear what calculations were performed on the data before ANOVAs carried out.	A - moderate B - moderate C - strong D - weak E - weak F - N/A Global: Weak
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METACOGNITION IN CHILDREN

Wojcik, Moulin & Souchay (2013).	18 participants with ASD (16 males; age $M = 12.60$ years, $SD = 2.14$) vs 19 TD participants (13 males; age $M = 11.83$ years, $SD = 2.57$). No group differences in age, VIQ and FSIQ, but a difference approaching significance in VIQ (therefore, this was used as a covariate in analysis).	Episodic FOK task: participants were presented with 20 word pairs (a cue word and a target word; on a laptop for 5sec each pair) and told their memory for these pairs would be tested later. Next participants were given cue words and asked to recall the target words. At this stage they were asked if they would be able to detect the target word amongst others (FOK judgment) with possible answers being 'yes' or 'no'. Afterwards a recognition test was given.	Episodic FOK task: a 2 (group) x 2 (prediction: yes/no) ANOVA revealed no significant main effect of group, $F(1, 34) = 1.14$, ns , $\eta p^2 = .049$, but a significant interaction, $F(1, 22) = 5.44$, $p < .02$, $\eta p^2 = .198$. Within-group t-tests showed TD participants were more accurate in their Yes/No FOK prediction judgments (recognition for Yes judgments higher than for No judgments), $t(13) = 3.14$, $p < .001$, $d = .777$ whereas this was not significant for the ASD condition, $t(11) = 0.05$, $n.s.$, $d = .007$. This suggests those with ASD are less accurate on prediction tasks than TD children, specifically tasks of episodic memory.	Strengths: tasks based on those used previously to investigate semantic and episodic FOK. Limitations: limited to yes/no answers on the task, using VIQ as a covariate was not statistically appropriate (Miller & Chapman, 2001).	A - weak B - moderate C - strong D - weak E - weak F - N/A Global: Weak
		Semantic FOK task: 40 target words with corresponding pictures. Participants were given each of the words and asked to define them. They were told these words would be presented later as pictures and asked to make a FOK yes/no judgment. They then took part in a recognition test.	Semantic FOK task: a 2 (group) x 2 (prediction: yes/no) ANOVA found no significant effect of group, $F(1, 34) = 0.00$, $n.s.$, $\eta p^2 = .001$. No interaction was found, $F(1, 29) = 1.09$, $n.s.$, $\eta p^2 = .036$, indicating that children with ASD could predict their future recognition using FOK judgments. This suggests there are no differences in predictive emergent awareness between children with and without ASD on tasks of semantic memory.		

METACOGNITION IN CHILDREN

Wojcik, Waterman, Lestie, Moulin, & Souchay (2014). Exp 1.	21 participants with ASD (18 males; age $M = 12.77$ years, $SD = 2.34$) vs 21 TD participants (17 males; age $M = 11.64$ years, $SD = 2.49$). No differences in age, PIQ, FSIQ or receptive vocabulary across groups.	Participants were given 12 word pairs to remember (presented for 8 s each) and then given an immediate (straight away) or delayed (2 mins later) JOL task (will you be able to recall the target word when you are shown the cue word? Yes/No). Afterwards they were asked to recall the word pairs.	A 2 (group) x 2 (condition: immediate/delayed recall) ANOVA revealed no significant group difference in recall performance, $F(1, 40) = 0.002$, $p = .97$, $\eta p^2 = .001$. There was no difference between groups in terms of level of prediction, $F(1, 40) = 0.18$, $p = .678$, $\eta p^2 = .004$. A 2 (group) x 2 (condition) ANOVA exploring relative accuracy of JOL revealed no significant differences in judgment of learning accuracy between those with and without ASD, $F(1, 40) = 1.51$, $p = .23$, $\eta p^2 = .03$. There was a significant effect of condition, $F(1, 40) = 84.97$, $p < .001$, $\eta p^2 = .68$, suggesting that across both groups immediate JOL were less accurate than delayed ones. These findings suggest no differences in predictive emergent awareness between children with and without ASD.	Strengths: groups matched on age and IQ, tasks based somewhat on previous research. Limitations: specific sample of those with ASD, as it was children who had a diagnosis of Asperger's or high-functioning autism.	A - moderate B - weak C - strong D - moderate E - weak F - N/A Global: Weak
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Note: ¹Articles that contain other participant conditions that were not described. ASD = Autistic Spectrum Disorder, TD = Typically Developing, M = mean, SD = Standard Deviation, QAT = Quality Assessment Tool, JOC = Judgment Of Confidence, FOK = Feeling Of Knowing, JOL = Judgment Of Learning, PJA = Performance Judgment Accuracy; IQ = Intelligence Quotient, BPVS = British Picture Vocabulary Scale, VIQ = Verbal IQ, VMA = Verbal Mental Age, PIQ = Performance IQ, FSIQ = Full Scale IQ, SRS = Social Responsiveness Scale, WASI = Wechsler Abbreviated Scale of Intelligence, ANOVA = Analysis of Variance.

Critical Summary

All of the ten articles included in this literature review report quasi-experimental studies comparing typically developing children and those with ASD on tasks of emergent awareness. The studies looked at offline emergent awareness (Krasny-Pacini et al., 2015): the thinking about a task that happens before (prediction) and after (evaluation) the particular task is carried out. No included studies measured 'true' online emergent awareness (Krasny-Pacini et al., 2015), or error detection, which occurs while a task is being carried out.

Overall the studies were assessed as having weak global quality ratings according to the QATQS tool (Thomas et al., 2004). For a global rating of 'weak' the paper has to have at least two weak ratings on the six sub-sections. All articles had weaknesses in blinding and data collection. They did not report if the researchers were aware of what group the participants were in when carrying out testing, whether the participants were aware of the research question, and if the tasks used were valid and reliable. This resulted in these two sub-sections (blinding and data collection) consistently being rated as weak across the ten articles. Another limitation was that they did not usually report the drop-out rate of participants at the time of sign-up, so it is unclear how many were approached and how many of those did not wish to take part. This could have led to a certain sub-section of the population taking part in the study, which could have influenced results.

Of the ten included articles, three looked at predictive emergent awareness, six looked at evaluative emergent awareness, and one looked at both. Children who took part in the studies were between the ages of nine and fourteen years old, and the majority of studies matched participants on age and IQ. This calls in to question whether the children with ASD were a true

METACOGNITION IN CHILDREN

representation of the population, or if they were more likely to be those with high-functioning ASD, as it is often these individuals that have a similar IQ to their peers (Siegel, Minshew, & Goldstein, 1996). More males took part in the studies than females; however, it could be argued that this is representative of those with ASD (Loomes, Hull, & Mandy, 2017).

Predictive Emergent Awareness

Wojcik, Moulin and Souchay (2013) explored participants' predictive emergent awareness using tasks that involved semantic (general knowledge) and episodic (word pairs) knowledge. They believed they would find that children with ASD performed worse than typically developing controls on a prediction task involving episodic, but not semantic, materials. This would provide evidence for the view put forward by Powell and Jordan (1993), which states that individuals with ASD have a specific cognitive deficit that means they are unable to encode information subjective to them. Wojcik et al.'s (2013) results supported this, as they only found significant differences in performance between typically developing children and those with ASD on the episodic task. On the other hand children with ASD performed as well as typically developing children on the semantic task. The authors suggested this was evidence that children with ASD cannot put themselves into the past to retrieve information, as the episodic task (unlike the semantic task) relied on the skill of children mentally going back and thinking about when they learned the information.

However, another research study, using a similar episodic task, does not appear to support these findings. Grainger, Williams, and Lind (2016a) also gave participants target-cue word pairs to learn, judgments of learning, and then asked them to recall the target words. Although the pattern of results suggested children with ASD were less accurate than typically developing children on the

METACOGNITION IN CHILDREN

judgments of learning, unlike Wojcik et al.'s (2013) study, these differences were not significant and the effect sizes were small. Both studies used similar age groups, numbers of participants, matched on aspects of IQ, and performed a similar data analysis. It is, therefore, unclear why there is a difference in the results.

Other research seems to support the findings of Grainger et al. (2016a) that there are no differences in predictive emergent awareness between children with and without ASD (Elmose & Happé, 2014; Wojcik, Waterman, Lestie, Moulin, & Souchay, 2014). Elmose and Happé (2014) explored prediction by asking participants to remember sequences of pictures (which were sequences of faces or buildings), and asking how many pictures they would remember in the same order. Interestingly performance judgments given by children with ASD were more accurate than typically developing children for the building sequence trials. However, a limitation of this study is that it did not match on age; therefore, the typically developing children appeared to be younger (age $M = 10.1$ years, $SD = 2.5$) than those with ASD (age $M = 13.4$, $SD = 1.5$). Previous research with typically developing children has found metacognition develops throughout childhood and adolescence (Kuhn, 2000; Weil et al., 2013), so the younger age group may have had less developed metacognition, which could have meant the different findings were due to age differences.

Overall the included studies in the review suggest that children with ASD do not have diminished predictive emergent awareness compared to those without ASD. Although three studies found a similar pattern that children with ASD performed worse on tasks of prediction (Grainger et al., 2016a; Wojcik et al., 2013; Wojcik et al., 2014), these were usually non-significant differences

METACOGNITION IN CHILDREN

and effect sizes were small. Only one study found a significant difference, on an episodic task (Wojcik et al., 2013). The other included study (Elmose & Happé, 2014) found evidence that on a particular task children with ASD performed better at prediction than typically developing controls. These findings suggest that overall children with ASD can perform as well as typically developing children on tasks where they have to predict their performance on a task.

Evaluative Emergent Awareness

The majority of studies identified by the review explored participants' ability to evaluate a task that they had completed, all using measures known as judgments of confidence. These measures involve participants completing a main task (such as answering questions or following sequences of instructions) and then being asked how well they thought they completed the task or how confident they were in their given answers. Out of the seven articles that explored participants' evaluative emergent awareness, four supported the hypothesis that this ability is diminished in children with ASD compared to typically developing controls (Brosnan et al., 2016; Grainger et al., 2016b; McMahon et al., 2016; Williams, Bergström, & Grainger, 2018). Effect sizes for these studies, where reported, ranged from small to large. This suggests there was a lack of consistency in the results across studies that found significant effects.

Three of the studies reviewed found no differences in evaluative emergent awareness skills between children with ASD and typically developing children (Elmose & Happé, 2014; Maras, Gamble, & Brosnan, 2019; Wojcik et al., 2011). These studies, similar to those that had found significant effects, used main tasks such as maths questions, a memory task, and instruction sequences. This indicates that it was perhaps not a difference in task design

METACOGNITION IN CHILDREN

that led to the difference in results. Also, looking at the means and standard deviations of these studies there did not appear to be a clear direction of the results between children with and without ASD, suggesting it was not under-powered studies affecting the results (Elmose & Happé, 2014; Maras et al., 2019; Wojcik et al., 2011). These studies seem to suggest that participants with ASD can perform as well as typically developing participants.

A limitation when trying to look at the overall results of the studies is that there was variability in the way participants could answer the judgments of confidence. Some studies provided set answers that the participants had to choose between (for example, 'right', 'wrong' and 'don't know' in Brosnan et al., 2016), whereas others provided Likert scales and asked participants to choose a number (for example, on a 10 point scale from 'I did not do very well' to 'I did very well' in Wojcik et al., 2011). Even the studies that all used Likert scales varied in the number of points on the scale and what each end of the scale meant. This makes the findings vulnerable to altering interpretations; therefore, they could be less valid than if similar measures were used.

It appears that there is evidence that both supports and provides evidence against children with ASD having diminished evaluative emergent awareness. Although the QATQS tool has poor precision, overall the findings from it suggest that none of the studies were rigorous and the differing results do not appear to be due to differences highlighted by this tool. The three studies that had slightly higher ratings on individual components (Maras et al., 2019; McMahon et al., 2016; Wojcik et al., 2011) did not have similar results. Therefore, it appears that no clear conclusion can be drawn from the studies investigating evaluative emergent awareness in children with and without ASD.

Discussion

The aim of this literature review was to explore if children with ASD have diminished emergent awareness compared to neuro-typical children. Emergent awareness consists of the abilities individuals use to monitor and regulate tasks they are carrying out (Krasny-Pacini et al., 2015). The model put forward by Krasny-Pacini et al. (2015) splits emergent awareness into online and offline awareness. Online awareness is the ability to monitor task performance and detect errors while the task is being carried out. The literature review did not include any studies that investigated this aspect of emergent awareness in children with ASD. This may have been due to the search criteria as it did not include ERP measures, which have been found to show differences between children with ASD and neuro-typical controls on error detection (Hüpen et al., 2016). However, these were excluded due to the evidence that ERP measures capture errors that participants are unaware of, as well as the ones that they are aware of (Hester et al., 2005; Nieuwenhuis et al., 2001).

In terms of offline awareness (Krasny-Pacini et al., 2015), the included studies looked at prediction and evaluation. The results from three studies appear to suggest that children with ASD perform as well as controls on measures where they have to predict their performance on a task (Elmose & Happé, 2014; Grainger et al., 2016a; Wojcik et al., 2014). Also, some of the articles that explored the evaluative emergent awareness suggested children with ASD performed as well on judgments of confidence as those without ASD (Elmose & Happé, 2014; Maras et al., 2019; Wojcik et al., 2011). This shows that, in at least some instances, children with ASD do not have reduced ability compared to children without ASD.

These findings do not support the theory that the cognitive mechanism

METACOGNITION IN CHILDREN

required to attribute mental states to others may also be responsible for attributing mental states to the self in ASD (Frith & Happé, 1999; Williams, 2010). It has been well-researched that children with ASD have poor theory of mind (Mazza et al., 2017). Frith and Happé (1999) put forward the theory that an individual's ability to attribute mental states to others is closely related to the same individual's ability to attribute mental states to themselves. Therefore, the neuro-cognitive deficit responsible for children's lack of theory of mind in ASD may also contribute to their lack of metacognitive self-awareness. Yet included studies have shown that, particularly for prediction tasks, children with ASD perform as well as typically developing children. This suggests that perhaps the theory that there is one underlying mechanism for both theory of mind and metacognition is too simplistic.

Further support for a more complex model of metacognition in children with ASD come from additional included studies showing a difference in the ability of children with and without ASD on measures of evaluation (Brosnan et al., 2016; McMahon et al., 2016; Grainger et al., 2016b; Williams et al., 2018) and prediction (Wojcik et al., 2013). These findings suggest that perhaps some children with ASD have diminished offline emergent awareness, but that others do not. It may be that metacognitive abilities are individualised and also distinct from one another, with potentially separate underlying mechanisms that may or may not be affected in ASD.

However, overall the results need to be interpreted with caution due to the limitations of the studies. Most suffered from small participant numbers, suggesting they may not have been powered to find differences. Where differences were found, although these were statistically significant, they may not have been clinically significant differences that would lead to problems in

METACOGNITION IN CHILDREN

children's functioning. Studies also used a specific age group of children (nine to fourteen years old) and so it is unknown if these findings would be similar in a younger or older sample.

Clinical Implications

The variability of findings suggests that it would be important to assess metacognition in children with ASD to determine their individual metacognitive profile. This would require multiple measures to capture the complexity of metacognition and determine if the child had weaknesses in specific areas of metacognition, for example, evaluative emergent awareness. It may be that measures need to be developed that look at clinically significant difficulties, rather than purely ones that show differences between children with ASD and typically developing children. This would help to tailor interventions as well.

These findings would also be clinically important for children's learning and education. It has been found that individuals with better metacognition can more accurately determine what they need to learn and implement guided strategies that allow them to study easier material first (Metcalf, 2009). Some of the studies included in the review suggest children with ASD have poorer emergent awareness evaluative ability (Brosnan et al., 2016 Grainger et al., 2016b; McMahon et al., 2016; Williams et al., 2018). This suggests they could perhaps skip learning material thinking they already know and may not always be able to determine what they should learn first. This would have an impact on their learning and academic achievement. It has been found that children with high-functioning ASD perform worse academically than their intellectual ability predicts (Estes, Rivera, Bryan, Cali, & Dawson, 2011). Therefore, it may be that school interventions teaching the use of metacognitive strategies to children with ASD are required. For example, in Maras et al.'s (2017) study they found

METACOGNITION IN CHILDREN

that providing feedback increased the accuracy of judgments, suggesting these types of interventions may be beneficial for children with ASD.

Limitations

One limitation of the literature review is that grey literature was not searched. Another is that studies looking at this research area may have been excluded due to the strict search terms and criteria on children with ASD requiring a formal diagnosis. This excluded participant groups with 'autism-like' features, which may have added to the results.

Another limitation of the studies overall was the amount of variation in the tasks used, how constructs were measured, analysis strategies and the findings across studies. This made it difficult to synthesise the results. One way this was overcome was to divide the results by predictive and evaluative emergent awareness abilities. However, even within these two different groups of results there was a lot of variability making it difficult to come to clear conclusions. Although performing a meta-analysis on the data could be beneficial to help with this issue, it may be that the methods are not consistent enough. Therefore, if one was carried out in the future it would be recommended that a measure of heterogeneity, such as I^2 (Higgins, Thompson, Deeks, & Altman, 2003) was used.

Future Research

The literature review highlighted that the majority of studies recruit children within a specific age category for their research. Children were between the ages of nine and fourteen. It may be that different results would be found if younger or older children took part, as it has been found metacognition develops throughout childhood and adolescence (Kuhn, 2000; Weil et al., 2013). This would enable the development of metacognition in children with

METACOGNITION IN CHILDREN

ASD to be studied, as it could be that metacognition in these individuals have an altered developmental trajectory.

The literature review has also highlighted that there appears to be a lack of studies investigating error detection in children with ASD. This is the online emergent awareness ability that monitors and regulates performance as a task is being carried out (Krasny-Pacini et al., 2015). There appears to be a need to develop tasks that measure when children are consciously aware they are making a mistake when carrying out a task, due to the limitations of ERP studies (Hester et al., 2005; Nieuwenhuis et al., 2001). These tasks would need to be suitable for children with ASD as well as neuro-typical controls.

Conclusion

This aim of this literature review was to explore whether children with ASD have diminished emergent awareness compared to those without ASD. Systematic searches across five databases resulted in ten articles being included in the review. These articles looked at children's predictive and evaluative emergent awareness, but not their error detection. The findings indicate that children with ASD could predict as well as typically developing children, but a more mixed picture emerged about their ability to evaluate their performance on a task. It highlights the need for further research to explore the development of metacognition in children with ASD.

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Appendix A

Quality Assessment Tool for Quantitative Studies

QUALITY ASSESSMENT TOOL FOR
QUANTITATIVE STUDIES

COMPONENT RATINGS

A) SELECTION BIAS

(Q1) Are the individuals selected to participate in the study likely to be representative of the target population?

- 1 Very likely
- 2 Somewhat likely
- 3 Not likely
- 4 Can't tell

(Q2) What percentage of selected individuals agreed to participate?

- 1 80 - 100% agreement
- 2 60 - 79% agreement
- 3 less than 60% agreement
- 4 Not applicable
- 5 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

B) STUDY DESIGN

Indicate the study design

- 1 Randomized controlled trial
- 2 Controlled clinical trial
- 3 Cohort analytic (two group pre + post)
- 4 Case-control
- 5 Cohort (one group pre + post (before and after))
- 6 Interrupted time series
- 7 Other specify _____
- 8 Can't tell

Was the study described as randomized? If NO, go to Component C.

No Yes

If Yes, was the method of randomization described? (See dictionary)

No Yes

If Yes, was the method appropriate? (See dictionary)

No Yes

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

METACOGNITION IN CHILDREN

C) CONFOUNDERS

(Q1) Were there important differences between groups prior to the intervention?

- 1 Yes
- 2 No
- 3 Can't tell

The following are examples of confounders:

- 1 Race
- 2 Sex
- 3 Marital status/family
- 4 Age
- 5 SES (income or class)
- 6 Education
- 7 Health status
- 8 Pre-intervention score on outcome measure

(Q2) If yes, indicate the percentage of relevant confounders that were controlled (either in the design (e.g. stratification, matching) or analysis)?

- 1 80 – 100% (most)
- 2 60 – 79% (some)
- 3 Less than 60% (few or none)
- 4 Can't Tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

D) BLINDING

(Q1) Was (were) the outcome assessor(s) aware of the intervention or exposure status of participants?

- 1 Yes
- 2 No
- 3 Can't tell

(Q2) Were the study participants aware of the research question?

- 1 Yes
- 2 No
- 3 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

E) DATA COLLECTION METHODS

(Q1) Were data collection tools shown to be valid?

- 1 Yes
- 2 No
- 3 Can't tell

(Q2) Were data collection tools shown to be reliable?

- 1 Yes
- 2 No
- 3 Can't tell

RATE THIS SECTION	STRONG	MODERATE	WEAK
See dictionary	1	2	3

METACOGNITION IN CHILDREN

F) WITHDRAWALS AND DROP-OUTS

(Q1) Were withdrawals and drop-outs reported in terms of numbers and/or reasons per group?

- 1 Yes
- 2 No
- 3 Can't tell
- 4 Not Applicable (i.e. one time surveys or interviews)

(Q2) Indicate the percentage of participants completing the study. (If the percentage differs by groups, record the lowest).

- 1 80 -100%
- 2 60 - 79%
- 3 less than 60%
- 4 Can't tell
- 5 Not Applicable (i.e. Retrospective case-control)

RATE THIS SECTION	STRONG	MODERATE	WEAK	
See dictionary	1	2	3	Not Applicable

G) INTERVENTION INTEGRITY

(Q1) What percentage of participants received the allocated intervention or exposure of interest?

- 1 80 -100%
- 2 60 - 79%
- 3 less than 60%
- 4 Can't tell

(Q2) Was the consistency of the intervention measured?

- 1 Yes
- 2 No
- 3 Can't tell

(Q3) Is it likely that subjects received an unintended intervention (contamination or co-intervention) that may influence the results?

- 4 Yes
- 5 No
- 6 Can't tell

H) ANALYSES

(Q1) Indicate the unit of allocation (circle one)

community organization/institution practice/office individual

(Q2) Indicate the unit of analysis (circle one)

community organization/institution practice/office individual

(Q3) Are the statistical methods appropriate for the study design?

- 1 Yes
- 2 No
- 3 Can't tell

(Q4) Is the analysis performed by intervention allocation status (i.e. intention to treat) rather than the actual intervention received?

- 1 Yes
- 2 No
- 3 Can't tell

METACOGNITION IN CHILDREN

GLOBAL RATING**COMPONENT RATINGS**

Please transcribe the information from the gray boxes on pages 1-4 onto this page. See dictionary on how to rate this section.

A	SELECTION BIAS	STRONG	MODERATE	WEAK
		1	2	3
B	STUDY DESIGN	STRONG	MODERATE	WEAK
		1	2	3
C	CONFOUNDERS	STRONG	MODERATE	WEAK
		1	2	3
D	BLINDING	STRONG	MODERATE	WEAK
		1	2	3
E	DATA COLLECTION METHOD	STRONG	MODERATE	WEAK
		1	2	3
F	WITHDRAWALS AND DROPOUTS	STRONG	MODERATE	WEAK
		1	2	3
				Not Applicable

GLOBAL RATING FOR THIS PAPER (circle one):

- | | | |
|---|----------|----------------------------|
| 1 | STRONG | (no WEAK ratings) |
| 2 | MODERATE | (one WEAK rating) |
| 3 | WEAK | (two or more WEAK ratings) |

With both reviewers discussing the ratings:

Is there a discrepancy between the two reviewers with respect to the component (A-F) ratings?

No Yes

If yes, indicate the reason for the discrepancy

- | | |
|---|---|
| 1 | Oversight |
| 2 | Differences in interpretation of criteria |
| 3 | Differences in interpretation of study |

Final decision of both reviewers (circle one):

- | | |
|---|----------|
| 1 | STRONG |
| 2 | MODERATE |
| 3 | WEAK |

Quality Assessment Tool for Quantitative Studies Dictionary



The purpose of this dictionary is to describe items in the tool thereby assisting raters to score study quality. Due to under-reporting or lack of clarity in the primary study, raters will need to make judgements about the extent that bias may be present. When making judgements about each component, raters should form their opinion based upon information contained in the study rather than making inferences about what the authors intended. Mixed methods studies can be quality assessed using this tool with the quantitative component of the study.

A) SELECTION BIAS

(Q1) Participants are more likely to be representative of the target population if they are randomly selected from a comprehensive list of individuals in the target population (score very likely). They may not be representative if they are referred from a source (e.g. clinic) in a systematic manner (score somewhat likely) or self-referred (score not likely).

(Q2) Refers to the % of subjects in the control and intervention groups that agreed to participate in the study before they were assigned to intervention or control groups.

B) STUDY DESIGN

In this section, raters assess the likelihood of bias due to the allocation process in an experimental study. For observational studies, raters assess the extent that assessments of exposure and outcome are likely to be independent. Generally, the type of design is a good indicator of the extent of bias. In stronger designs, an equivalent control group is present and the allocation process is such that the investigators are unable to predict the sequence.

Randomized Controlled Trial (RCT)

An experimental design where investigators randomly allocate eligible people to an intervention or control group. A rater should describe a study as an RCT if the randomization sequence allows each study participant to have the same chance of receiving each intervention and the investigators could not predict which intervention was next. If the investigators do not describe the allocation process and only use the words 'random' or 'randomly', the study is described as a controlled clinical trial.

See below for more details.

Was the study described as randomized?

Score YES, if the authors used words such as random allocation, randomly assigned, and random assignment.

Score NO, if no mention of randomization is made.

Was the method of randomization described?

Score YES, if the authors describe any method used to generate a random allocation sequence.

Score NO, if the authors do not describe the allocation method or describe methods of allocation such as alternation, case record numbers, dates of birth, day of the week, and any allocation procedure that is entirely transparent before assignment, such as an open list of random numbers of assignments.

If NO is scored, then the study is a controlled clinical trial.

METACOGNITION IN CHILDREN

Was the method appropriate?

Score YES, if the randomization sequence allowed each study participant to have the same chance of receiving each intervention and the investigators could not predict which intervention was next. Examples of appropriate approaches include assignment of subjects by a central office unaware of subject characteristics, or sequentially numbered, sealed, opaque envelopes.

Score NO, if the randomization sequence is open to the individuals responsible for recruiting and allocating participants or providing the intervention, since those individuals can influence the allocation process, either knowingly or unknowingly.

If NO is scored, then the study is a controlled clinical trial.

Controlled Clinical Trial (CCT)

An experimental study design where the method of allocating study subjects to intervention or control groups is open to individuals responsible for recruiting subjects or providing the intervention. The method of allocation is transparent before assignment, e.g. an open list of random numbers or allocation by date of birth, etc.

Cohort analytic (two group pre and post)

An observational study design where groups are assembled according to whether or not exposure to the intervention has occurred. Exposure to the intervention is not under the control of the investigators. Study groups might be non-equivalent or not comparable on some feature that affects outcome.

Case control study

A retrospective study design where the investigators gather 'cases' of people who already have the outcome of interest and 'controls' who do not. Both groups are then questioned or their records examined about whether they received the intervention exposure of interest.

Cohort (one group pre + post (before and after))

The same group is pretested, given an intervention, and tested immediately after the intervention. The intervention group, by means of the pretest, act as their own control group.

Interrupted time series

A study that uses observations at multiple time points before and after an intervention (the 'interruption'). The design attempts to detect whether the intervention has had an effect significantly greater than any underlying trend over time. Exclusion: Studies that do not have a clearly defined point in time when the intervention occurred and at least three data points before and three after the intervention

Other:

One time surveys or interviews

C) **CONFOUNDERS**

By definition, a confounder is a variable that is associated with the intervention or exposure and causally related to the outcome of interest. Even in a robust study design, groups may not be balanced with respect to important variables prior to the intervention. The authors should indicate if confounders were controlled in the design (by stratification or matching) or in the analysis. If the allocation to intervention and control groups is randomized, the authors must report that the groups were balanced at baseline with respect to confounders (either in the text or a table).

D) **BLINDING**

(Q1) Assessors should be described as blinded to which participants were in the control and intervention groups. The purpose of blinding the outcome assessors (who might also be the care providers) is to protect against detection bias.

(Q2) Study participants should not be aware of (i.e. blinded to) the research question. The purpose of blinding the participants is to protect against reporting bias.

METACOGNITION IN CHILDREN

E) DATA COLLECTION METHODS

Tools for primary outcome measures must be described as reliable and valid. If 'face' validity or 'content' validity has been demonstrated, this is acceptable. Some sources from which data may be collected are described below:

Self reported data includes data that is collected from participants in the study (e.g. completing a questionnaire, survey, answering questions during an interview, etc.).

Assessment/Screening includes objective data that is retrieved by the researchers. (e.g. observations by investigators).

Medical Records/Vital Statistics refers to the types of formal records used for the extraction of the data.

Reliability and validity can be reported in the study or in a separate study. For example, some standard assessment tools have known reliability and validity.

F) WITHDRAWALS AND DROP-OUTS

Score **YES** if the authors describe BOTH the numbers and reasons for withdrawals and drop-outs.

Score **NO** if either the numbers or reasons for withdrawals and drop-outs are not reported.

Score **NOT APPLICABLE** if the study was a one-time interview or survey where there was not follow-up data reported.

The percentage of participants completing the study refers to the % of subjects remaining in the study at the final data collection period in all groups (i.e. control and intervention groups).

G) INTERVENTION INTEGRITY

The number of participants receiving the intended intervention should be noted (consider both frequency and intensity). For example, the authors may have reported that at least 80 percent of the participants received the complete intervention. The authors should describe a method of measuring if the intervention was provided to all participants the same way. As well, the authors should indicate if subjects received an unintended intervention that may have influenced the outcomes. For example, co-intervention occurs when the study group receives an additional intervention (other than that intended). In this case, it is possible that the effect of the intervention may be over-estimated. Contamination refers to situations where the control group accidentally receives the study intervention. This could result in an under-estimation of the impact of the intervention.

H) ANALYSIS APPROPRIATE TO QUESTION

Was the quantitative analysis appropriate to the research question being asked?

An intention-to-treat analysis is one in which all the participants in a trial are analyzed according to the intervention to which they were allocated, whether they received it or not. Intention-to-treat analyses are favoured in assessments of effectiveness as they mirror the noncompliance and treatment changes that are likely to occur when the intervention is used in practice, and because of the risk of attrition bias when participants are excluded from the analysis.

METACOGNITION IN CHILDREN

Component Ratings of Study:

For each of the six components A – F, use the following descriptions as a roadmap.

A) SELECTION BIAS

Good: The selected individuals are very likely to be representative of the target population (Q1 is 1) and there is greater than 80% participation (Q2 is 1).

Fair: The selected individuals are at least somewhat likely to be representative of the target population (Q1 is 1 or 2); and there is 60 - 79% participation (Q2 is 2). 'Moderate' may also be assigned if Q1 is 1 or 2 and Q2 is 5 (can't tell).

Poor: The selected individuals are not likely to be representative of the target population (Q1 is 3); or there is less than 60% participation (Q2 is 3) or selection is not described (Q1 is 4); and the level of participation is not described (Q2 is 5).

B) DESIGN

Good: will be assigned to those articles that described RCTs and CCTs.

Fair: will be assigned to those that described a cohort analytic study, a case control study, a cohort design, or an interrupted time series.

Weak: will be assigned to those that used any other method or did not state the method used.

C) CONFOUNDERS

Good: will be assigned to those articles that controlled for at least 80% of relevant confounders (Q1 is 2); or (Q2 is 1).

Fair: will be given to those studies that controlled for 60 – 79% of relevant confounders (Q1 is 1) and (Q2 is 2).

Poor: will be assigned when less than 60% of relevant confounders were controlled (Q1 is 1) and (Q2 is 3) or control of confounders was not described (Q1 is 3) and (Q2 is 4).

D) BLINDING

Good: The outcome assessor is not aware of the intervention status of participants (Q1 is 2); and the study participants are not aware of the research question (Q2 is 2).

Fair: The outcome assessor is not aware of the intervention status of participants (Q1 is 2); or the study participants are not aware of the research question (Q2 is 2).

Poor: The outcome assessor is aware of the intervention status of participants (Q1 is 1); and the study participants are aware of the research question (Q2 is 1); or blinding is not described (Q1 is 3 and Q2 is 3).

E) DATA COLLECTION METHODS

Good: The data collection tools have been shown to be valid (Q1 is 1); and the data collection tools have been shown to be reliable (Q2 is 1).

Fair: The data collection tools have been shown to be valid (Q1 is 1); and the data collection tools have not been shown to be reliable (Q2 is 2) or reliability is not described (Q2 is 3).

Poor: The data collection tools have not been shown to be valid (Q1 is 2) or both reliability and validity are not described (Q1 is 3 and Q2 is 3).

F) WITHDRAWALS AND DROP-OUTS - a rating of:

Good: will be assigned when the follow-up rate is 80% or greater (Q1 is 1 and Q2 is 1).

Fair: will be assigned when the follow-up rate is 60 – 79% (Q2 is 2) OR Q1 is 4 or Q2 is 5.

Poor: will be assigned when a follow-up rate is less than 60% (Q2 is 3) or if the withdrawals and drop-outs were not described (Q1 is No or Q2 is 4).

Not Applicable: if Q1 is 4 or Q2 is 5.

Appendix B**Preparation and Submission Requirements for the *Journal of Autism and Developmental Disorders*****Scope of the Journal**

The Journal of Autism and Developmental Disorders seeks to advance theoretical and applied research as well as examine and evaluate clinical diagnoses and treatments for autism and related disabilities. JADD encourages research submissions on the causes of ASDs and related disorders, including genetic, immunological, and environmental factors; diagnosis and assessment tools (e.g., for early detection as well as behavioural and communications characteristics); and prevention and treatment options.

Submission of a manuscript implies: that the work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all co-authors, if any, as well as by the responsible authorities – tacitly or explicitly – at the institute where the work has been carried out.

Manuscript Preparation

Submissions consist of: A title page with the running head, manuscript title, and complete author information; followed by (page break) the Abstract page with keywords and the corresponding author e-mail information; the blinded manuscript containing no author information (no name, no affiliation, and so forth); and the Author Note.

Article length is 20-23 double-spaced manuscript pages long (not including title page, abstract, tables, figures, addendums, etc.) Manuscripts of 40 double-spaced pages (references, tables and figures counted as pages) have been published.

Title

The title page should include:

- The name(s) of the author(s)
- A concise and informative title
- The affiliation(s) and address(es) of the author(s)
- The e-mail address, telephone and fax numbers of the corresponding author

Abstract

The abstract should be 120 words or less. It should not contain any undefined abbreviations or unspecified references.

Formatting

- Manuscripts should be submitted in Word.
- Use a normal, plain font (e.g., 10-point Times Roman) for text.

METACOGNITION IN CHILDREN

- Use italics for emphasis.
- Use the automatic page numbering function to number the pages.
- Do not use field functions.
- Use tab stops or other commands for indents, not the space bar.
- Use the table function, not spreadsheets, to make tables.
- Use the equation editor or MathType for equations.

Body of Text

The body of the manuscript should begin on a separate page. The manuscript page header (if used) and page number should appear in the upper right corner. Type the title of the paper centered at the top of the page, add a hard return, and then begin the text using the format noted above. The body should contain:

- Introduction (The introduction has no label.)
- Methods (Center the heading. Use un-centered subheadings such as: Participants, Materials, Procedure.)
- Results (Center the heading.)
- Discussion (Center the heading.)

Tables

- All tables are to be numbered using Arabic numerals.
- Tables should always be cited in text in consecutive numerical order.
- For each table, please supply a table caption (title) explaining the components of the table.
- Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.
- Footnotes to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data) and included beneath the table body.

Each table should be inserted on a separate page at the back of the manuscript in the order noted above. A call-out for the correct placement of each table should be included in brackets within the text immediately after the phrase in which it is first mentioned. Copyright permission footnotes for tables are typed as a table note.

Figures

Each figure should appear on a separate page. The page where the figure is found should have the figure number and the word "top"[ie, Figure 1 top] typed above the figure. Figures or illustrations (photographs, drawings, diagrams, and charts) are to be numbered in one consecutive series of arabic numerals. Figures may be embedded in the text of a Word or Wordperfect document.



SCHOOL OF PSYCHOLOGY

DOCTORATE IN CLINICAL PSYCHOLOGY

EMPIRICAL PAPER

Metacognition in Children: How do the emergent awareness abilities of prediction, error detection and evaluation change by age?

Trainee Name: **Rebecca Tegen Jenkin**

Primary Research Supervisor: **Dr Jenny Limond**

Senior Lecturer and Research Director for
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Secondary Research Supervisor: **Dr Nick Moberley**

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Target Journal: Consciousness and Cognition

Word Count: 7637 words (excluding abstract, table of contents, list of figures, references, footnotes, appendices)

**Submitted in partial fulfilment of requirements for the Doctorate Degree in
Clinical Psychology, University of Exeter**

Abstract

Objective: Metacognition can be defined as an individual's knowledge and beliefs about their thinking abilities (metacognitive knowledge) as well as the cognitive processes that monitor and regulate their actions (metacognitive skills). The current study explored children's metacognitive skills of prediction, error detection, and evaluation (known as emergent awareness), and how these relate to their subjective metacognitive knowledge, in younger ($M = 7.55$, $SD = 0.56$) and older children (age $M = 11.14$, $SD = 0.35$).

Methods: 135 participants (68 in the younger group), recruited from one Secondary School and two Primary Schools, were individually tested on measures of prediction, error detection and evaluation. They also completed a metacognitive knowledge questionnaire measuring their subjective awareness about their learning.

Results: Independent t -tests found significant differences between younger and older participants' predictive, error detecting, and evaluative emergent awareness. The differences suggested older children were more accurate than younger children on tasks of prediction and error detection but not evaluation. Older participants also scored significantly lower on the subjective metacognitive knowledge questionnaire, suggesting younger participants were more confident in their skills and strategies for learning. Correlation analysis found no relationships between the three emergent awareness abilities and metacognitive knowledge at either age, and only a significant difference between the prediction and evaluation correlation coefficients between age groups, suggesting the relationship between these abilities becomes weaker as children get older.

METACOGNITION IN CHILDREN

Conclusion: This study provides support for the hypotheses that emergent awareness skills become more accurate as children get older, but only for error detection and prediction tasks. Younger children are more confident in their learning and the strategies they use to learn. The results also suggest that all of these abilities are different from each other and may become more differentiated as children get older.

Keywords: Children, metacognition, emergent awareness.

Introduction

Metacognition was first defined as individuals' knowledge and regulation of their cognitions in relation to their learning (Flavell, 1979). Since then the area of research has expanded and there is now a variety of terms used to define and describe metacognition (Veenman, Van Hout-Wolters, & Afflerbach, 2006), but it is essentially our ability to consciously reflect on our thoughts and behaviour (Metcalfe, 1996). One aspect of metacognition is an individual's *metacognitive knowledge*: our thoughts and beliefs about how we learn and what affects it (Flavell, 1979). In one model metacognition also encompasses *emergent awareness*, which is used while carrying out tasks to monitor and regulate what we are doing (Krasny-Pacini et al., 2015). It includes skills such as our abilities to predict, error detect, and evaluate our performance on the specific task (Krasny-Pacini et al., 2015). Basic metacognition has been observed in children as young as three years old (Bernard, Proust, & Clément, 2015; Coughlin, Hembacher, Lyons, & Ghetti, 2015) and it continues to develop through childhood (Kuhn, 2000) and adolescence to adulthood (Weil et al., 2013).

Metacognition is considered part of, or at least closely linked to, executive functions (Fernandez-Duque, Baird, & Posner, 2000); the brain's control system responsible for actions such as self-regulation, goal setting, reasoning, and problem solving (Anderson, 2002). Therefore, similar to executive functions, metacognition may be clinically important for children who have neurodevelopmental disorders (Grainger, Williams, & Lind, 2016; Shen, Tsai, & Duann, 2011) and health conditions that affect cognition (Kizony, Tau, Bar, & Yeger, 2014). Indeed, studies have found that children with autistic spectrum disorder may have diminished metacognitive ability (Brosnan et al.,

METACOGNITION IN CHILDREN

2016; Grainger et al., 2016; Williams, Bergström, & Grainger, 2018) and those with Attention Deficit Hyperactivity Disorder (ADHD) appear to struggle with error detection (Liotti, Pliszka, Perez, Kothmann, & Woldorff, 2005; Shen et al., 2011) when compared to neuro-typical children. There is also evidence suggesting that children with brain injury have poorer metacognition than controls (Josman, Berney, & Jarus, 2000; Kizony et al., 2014). It would, therefore, be important when working with these populations to consider these possible deficits and their effects.

Another area where there has been interest in children's metacognition is education (Quigley, Muijs, & Stringer, 2018). The results of some studies have suggested that children with higher levels of metacognition may learn better (Desoete, Roeyers, & Buysse, 2001; Özsoy, 2011; Veenman, Wilhelm, & Beishuizen, 2004). This has led to guidance being published outlining methods schools and teachers can use to increase their students' metacognitive abilities, in hopes that it increases educational attainment as well (Quigley et al., 2018). However, other research has highlighted that not all aspects of metacognition develop in a straightforward linear way (Karably & Zabucky, 2017; Schneider, 2008) and that cognitive immaturity may be beneficial for children in the long term (Bjorklund, 2018).

Bjorklund (2018) puts forward an argument from an evolutionary developmental psychological perspective that children's cognitions at different stages in their development are adaptive for their environment, helping them to deal with their current context, rather than being cognitive limitations that need to be overcome. In terms of metacognition, poor metacognitive knowledge and skills in early childhood may be adaptive (Bjorklund & Green, 1992) and result in long-term benefits (Bjorklund, Periss, & Causey, 2009), as being

METACOGNITION IN CHILDREN

unrealistically optimistic about their learning ability allows children to explore strategies for learning and makes them less fearful of failure (Bjorklund, 1997). It also motivates persistence and protects children from learned helplessness (Bjorklund et al., 2009). Therefore, educational guidelines calling for all children to learn metacognitive strategies (Quigley et al., 2018) may be detrimental at some ages for some children's cognitive development and learning.

If metacognition is related to learned helplessness in children, it could also be related to their mental health, as it has been found that there is a link between learned helplessness, academic achievement and depression in children (Valås, 2001). This link between metacognition and mental health has been explored with adult participants, with results suggesting poor metacognition in adulthood is linked to poorer outcomes for individuals' mental health (Janeck, Calamari, Riemann, & Heffelfinger, 2003; Papageorgiou & Wells, 2003; Wells, 2005). Research suggests metacognition may play a part in a range of mental health disorders, such as depression (Papageorgiou & Wells, 2003), anxiety (Wells, 2005), schizophrenia (Lysaker et al., 2008) and obsessive compulsive disorder (Janeck et al., 2003). This may be due to an individual's metacognitive beliefs leading to inflexible and maladaptive responses to thought patterns (Wells, 2000), or their beliefs leading to the thought patterns directly (for example, the utility of rumination; Smith & Alloy, 2009).

In typically developing children, aspects of metacognition have been explored, such as their emergent awareness ability of evaluation (Freeman, Karayanidis, & Chalmers, 2017) and prediction (Schneider, Visé, Lockl, & Nelson, 2000), as well as metacognitive knowledge (Sperling, Howard, Miller, & Murphy, 2002). Krasny-Pacini et al.'s (2015) model of emergent awareness also

METACOGNITION IN CHILDREN

includes error detection. The current literature around this ability in children is limited, and focuses more on clinical populations (Hüpen, Groen, Gaastra, Tucha, & Tucha, 2016; Liotti et al., 2005; Krasny-Pacini et al., 2015). Yet, from a clinical perspective it is important to understand the typical development of all aspects of emergent awareness to inform work with clinical populations. For the same reason it would also be important to understand how the different emergent awareness abilities relate to each other.

The current study explored metacognition in children, using Krasny-Pacini et al.'s (2015) model of emergent awareness. The aim was to explore typically developing children's prediction, error detection, and evaluation abilities, how the relationships between them change by age, and how they relate to children's awareness of these skills. If cognitive immaturity is beneficial for young children (Bjorklund, 2018) it would be expected that this age group would be less accurate on tasks of prediction, evaluation and error detection. For the same reason they may be more confident than older children in their learning ability, assessed in this study using a subjective measure of metacognitive knowledge.

Research Questions and Hypotheses

The study addressed the following research questions:

- a) How do children's emergent awareness abilities of prediction, error detection and evaluation differ between younger and older children?
- b) Is there a relationship between prediction, error detection and evaluation? Does this differ between younger and older children?
- c) How does children's subjective metacognitive knowledge differ in younger and older children? How do children's emergent awareness

METACOGNITION IN CHILDREN

abilities relate to their subjective metacognitive knowledge in these age groups?

The hypotheses for the research questions were:

1. Children's prediction, error detection and evaluation abilities will all be more accurate in older children compared to younger children.
2. There is a positive relationship between the emergent awareness abilities of prediction, error detection and evaluation.
3. The relationships between children's prediction, error detection, and evaluation abilities will be stronger in older children compared to younger children.
4. Younger children will be more confident in their subjective metacognitive knowledge than the older age group.
5. The relationship between children's subjective metacognitive knowledge and emergent awareness (prediction, error detection and evaluation) will change between groups: younger children will more confident in their abilities but be less accurate on tasks of emergent awareness, whereas older children will have lower confidence in their knowledge but higher emergent awareness.

Method

Participants

One hundred and thirty-five children took part, recruited from Primary and Secondary Schools in England. There were 68 children in the younger group (36 females and 32 males; age $M = 7.55$, $SD = 0.56$) and 67 children in the older group (36 females and 31 males; age $M = 11.14$, $SD = 0.35$). Written, informed consent was gained from every participant, their parent/carer, their

METACOGNITION IN CHILDREN

teacher and headteacher before they took part. The inclusion criteria was any school child with the relevant consent; there was no other exclusion criteria.

Power Analyses

Power analysis was conducted using G*Power. For the first research question independent *t*-tests were used to compare two groups (age) on a specific measure (either prediction, error detection, or evaluation). A medium effect size guideline is .5 (Cohen, 1988). Therefore, with an effect size of $d = .5$, two-tailed alpha of .05, and 80% power, 128 participants were required (64 per group). For the second and third research questions a sensitivity power analysis was performed to see what variance could be explained in a correlation (two independent Pearson's *r*'s) of $n = 128$ with 80% power. This revealed an effect size of 0.45, which was considered acceptable.

Design

A quasi-experimental design was used, with a younger and older age group. To explore participants' emergent awareness skills they completed measures of prediction, error detection and evaluation. They also completed a questionnaire as a measure of subjective metacognitive knowledge. The researcher was not blinded to the two groups.

Materials

The Junior Metacognitive Assessment Inventory. The Junior Metacognitive Assessment Inventory (Jr. MAI) is a self-report questionnaire used to assess participant's confidence in their skills and strategies for learning (Sperling et al., 2002). This is part of individuals' metacognitive knowledge (Flavell, 1979). As a self-report measure this would capture participants'

METACOGNITION IN CHILDREN

subjective metacognitive knowledge. The Jr. MAI is based on the adult Metacognitive Awareness Inventory (Schraw & Dennison, 1994).

There were two versions of the Jr. MAI questionnaire (see Appendix A) created for younger (ages 8-11 years old) and older (11-15 years old) children. Both were used in the study: version A with the younger age group and version B with the older age group. Both versions of the questionnaires instructed participants to read the sentences and circle the answer that most relates to how they do their schoolwork. Version A consists of 12 items and uses a three-point Likert scale response (*Never, Sometimes, Always*), and version B includes six additional items and uses a five-point Likert scale (*Never, Seldom, Sometimes, Often, Always*). Although the Likert scales were different lengths, for this study the answers were weighted the same: Never weighted as 1; Sometimes as 3; and Always as 5.

The first 12 items from each of the two versions of the Jr. MAI's were considered in the analysis. This is because these were the same questions in both versions. A mean score for each participant was calculated from the 12 items. A higher score indicated more confidence in their ability. This became their metacognitive knowledge score.

The Dual-task Attention to Response Task. The Dual-task Attention to Response Task (DART; Dockree et al., 2006) is a computer-based go-no go test. It was extended into a test of error detection by O'Keeffe, Dockree, Moloney, Carton, and Robertson (2007). The DART has been used with children as a sustained attention and response inhibition task (Caspersen & Habekost, 2013), but has not included the additional error detection component. It was used in this study to measure prediction and error detection.

METACOGNITION IN CHILDREN

During the test the numbers 1-9 flashed up on the screen after a centrally placed fixation cross, for a duration of 150 ms each. The numbers were presented in 25 test rounds with a break in the middle. They were in a fixed series (1-9) for younger participants and in a random series for older participants, to ensure older participants made errors on the task.

Participants were instructed to press the response key “n” following each white number (go trials), except when the number three was presented (no-go trials). In addition, some of the numbers were presented as grey digits in an unpredictable pattern. When these appeared participants had to press the response key “v”. Digits were presented on a dark grey background, the go numbers were white in colour, and the rare grey digits were presented in a light grey colour.

As in previous studies, to make the DART an online emergent awareness test, participants were asked to indicate when they had made a mistake (Dockree, Tarleton, Carton, & FitzGerald, 2015) by saying ‘oops’. However, to make the task easier, participants were asked to indicate when they had made any mistake (and so this included errors of commission and omission), rather than just those of commission. They were given six practice rounds before the task began: three where they practised the response keys and three where they practised the response keys and saying ‘oops’. This stepped approach meant that the participants gradually learned what the task required. After the practice rounds participants were told how many rounds there were in the task and asked how many errors they believed they would make, as a measure of prediction. If the participant replied that they ‘didn’t know’ or were ‘unsure’, or did not give a specific answer such as ‘a few’ they were asked to give a specific number if they could, but were not pushed on this.

METACOGNITION IN CHILDREN

The computer recorded the number of errors each participant made. The total of these became a total error score. The number of times a participant identified an error (by saying 'oops') was recorded by the researcher. This became their total aware errors score. An overall error detection percentage score was calculated for each participant by dividing their total aware errors score (how many times the participants identified when they had made errors) by their total error score (how many errors the participants made during the DART; Dockree et al., 2015). A higher percentage indicated that participants were more aware of the errors they were making.

The DART has not been previously used to measure prediction, but in a previous study looking at prediction, using judgments of learning, a percentage prediction score was calculated and compared to the actual error percentage score (Wojcik, Waterman, Lestié, Moulin, & Souchay, 2014). As the DART consisted of 25 rounds of nine numbers, there were a total of 225 trials. The prediction percentage score was calculated by dividing participants' prediction scores by the number of trials (225). An actual error percentage score was calculated by dividing participants' total error scores by the number of trials. The difference between the two scores was calculated by taking away the actual error percentage score from the prediction percentage score. A smaller difference score indicated better prediction ability.

Judgment of Confidence task. This measured participants' evaluative ability. It was based on the Judgment of Confidence (JOC) task used by Grainger et al. (2016). It involved participants watching a short educational video on the computer about Eastern Gray kangaroos (https://www.youtube.com/watch?v=-nQzs_4WhO0). Once the video had finished the participants were given 16 questions about kangaroos (see

METACOGNITION IN CHILDREN

Appendix B), answers to which had been presented in the video. As per Grainger et al. (2016), the questions included four easy and four very difficult items. Participants were asked to provide answers to all the questions, and were told if they were unsure they should guess. However, a lot of participants left questions unanswered, and in these cases the researcher asked for a reason why the questions had been left.

On the other side of the page to the questions were the JOC scales, folded over while the participants answered the 16 questions so they were not visible. Afterwards, this part of each page was folded back, and participants were asked to rate how confident they were in each of their 16 answers on a 7-point Likert rating scale (from *extremely unsure* to *extremely sure*). The rating scale was fully explained to participants and it was checked that they understood what they were required to do before they began. Participants' accuracy and confidence scores were recorded for each question.

The average confidence judgment scores for both the correct answers and the incorrect answers were calculated. The difference between these two scores was then calculated, labelled participants' JOC difference score, with a larger difference between these two scores indicating better evaluative accuracy.

Procedure

Ethical approval was obtained from the University of Exeter Psychology Research Ethics Committee (see Appendix C for the letter of approval). Schools were approached through convenience sampling. A flowchart showing the recruitment process can be seen in Figure 1. Information sheets outlining the research and what was involved in taking part (see Appendix D), were emailed to schools. If the headteacher emailed back expressing interest then an

METACOGNITION IN CHILDREN

individual meeting was set up between the headteacher and the researcher, to discuss the project further and answer any questions. The researcher also offered to attend teacher, governor, and/or parent meetings to explain the research. This only happened in one school. Written consent was gained from the headteachers and the teachers of the classes identified as those who were eligible to take part (see Appendix E).

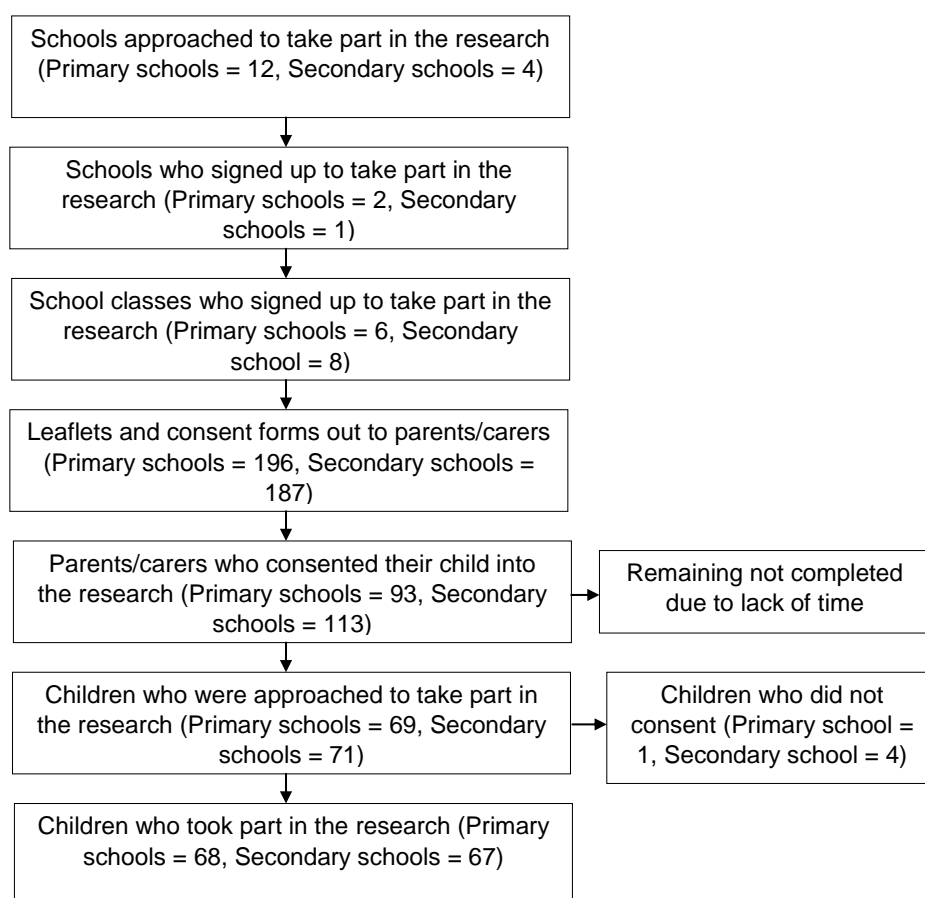


Figure 1: Flowchart showing recruitment of participants.

Parents/carers of children in the identified classes were sent information leaflets and consent forms (see Appendix F). These were sent out at least two weeks before the research began in the school. The consent forms were opt-in and parents/carers were asked to sign them and return them to school if they

METACOGNITION IN CHILDREN

gave consent for their child to take part. Children did not take part without written parent/carer consent.

The research was carried out in school time, on a table in a room or in a corridor allocated to the researcher. All children were tested individually. Before testing the researcher went into each class, introduced herself, and explained what the study was about. She made it clear that the children did not have to take part if they did not want to. The teacher was shown the parent/carer consent forms (of children who had parent/carer consent), identified the children, and asked the children if they would like to take part. If they agreed they were taken out of class by the researcher. The study took approximately 30 minutes per child.

The procedure was firstly piloted with a small sample of children ($N = 6$; these children had the necessary consent to take part). It took approximately 30 minutes for each participant to complete the study. The participant was read an information sheet (see Appendix G) by the researcher and asked if they had any questions. They were reminded that they did not have to take part and could withdraw from the study at any point without any repercussions. If they agreed to take part then the researcher went through the consent form (see Appendix G) and asked the participant to sign it. The researcher recorded the participant's age and gender.

Participants completed the Jr MAI, the DART and the JOC measures. The measures were carried out in the same order for every participant. Participants were made aware that they could choose not to take part in any of these measures. Once the three measures had been completed a debrief sheet was given to each participant (see Appendix G). This explained the procedure for removing their data at a later time should they wish (up to three months

METACOGNITION IN CHILDREN

afterwards). Participants were thanked for taking part in the study and taken back to their class.

Proposed Data Analysis Strategy

How do children's emergent awareness abilities of prediction, error detection and evaluation differ between younger and older children?

Error detection. The means and standard deviations were calculated for the total error scores, total aware errors scores and overall error detection percentage scores by age. An independent measures *t*-test was carried out on the error detection percentage scores to determine if there was a significant difference between the younger and older participants' error detection scores.

Prediction. The means and standard deviations were calculated for the percentage prediction score, actual error score, and the difference between these scores (difference prediction percentage scores) by age. An independent measures *t*-test was performed on the difference prediction percentage scores to determine if there was a significant difference between the younger and older participants' scores.

Evaluation. The analysis was based on that used by Grainger et al. (2016) to determine metacognitive monitoring accuracy. The means and standard deviations of participants' average confidence judgment scores for their correct answers and their incorrect answers, as well as the difference between these two scores were calculated by the two age groups. A larger difference between these two scores indicated more accurate evaluation. An independent measures *t*-test was carried out on the difference scores to determine if there was a significant difference between the younger and older participants' evaluation scores.

METACOGNITION IN CHILDREN

Second, Goodman and Kruskal's (1979) gamma scores were calculated for each participant's JOC scores, which take chance into consideration. To calculate gamma scores the formula $G = (P-Q)/(P+Q)$, where P is the number of cases ranked in the same order on both variables and Q is the number of cases ranked in reverse order. However, as gamma scores cannot be calculated when two or more cases are 0, raw data was adjusted using Snodgrass and Corwin's (1988) correction. This adds 0.5 to each frequency and divides the number by the overall number of confidence judgments made (N) plus one ($N + 1$). The calculated gamma correlations range from 1 to -1: a score of 0 indicates chance-level accuracy; a large positive value indicates participants' answers and confidence ratings are similar; and negative scores indicate an inverse relationship. Therefore, a larger gamma score indicates higher evaluative ability.

Is there a relationship between prediction, error detection and evaluation? Does this differ between younger and older children? First, the JOC gamma correlations were transformed using Fisher's r -to- z transformation, to ensure the sampling distribution was roughly normal and its variance more equal across the range of correlations. Correlations between the prediction percentage scores (prediction), error detection percentage scores (error detection) and JOC gamma (evaluation) scores by age were calculated. These revealed if there were relationships between these variables within the two different age groups.

The two corresponding correlation coefficients were then compared across age groups to assess the significance of the difference between them. This was completed using the Fisher r -to- z transformation.

METACOGNITION IN CHILDREN

How does children's subjective metacognitive knowledge differ in younger and older children? How do children's emergent awareness abilities relate to their subjective metacognitive knowledge in these age groups? First, the means and standard deviations were calculated for the subjective metacognitive knowledge scores. An independent measures *t*-test was carried out on these scores to determine if there was a significant difference between the younger and older participants' metacognitive knowledge.

Then correlations between the subjective metacognitive knowledge, prediction, error detection and evaluation scores were calculated for the younger and older age groups. These revealed if there were relationships between subjective metacognitive knowledge and emergent awareness abilities within the two different age groups. As previously, each of the corresponding correlation coefficients was assessed for significant difference between each age group using the Fisher *r*-to-*z* transformation.

Results

The sample size was large enough that under the central limit theorem normality assumptions were met. Outliers (defined as any value whose distance from the nearest quartile is greater than 1.5 times the interquartile range) were included in the data analysis. The analysis was also run with outliers removed, and where significant differences in the results were found, these were reported.

How do children's emergent awareness abilities of prediction, error detection and evaluation differ between younger and older children?

Error detection. One participant in the younger age group did not take part in the DART, as after viewing the instructions declined to take part. The

METACOGNITION IN CHILDREN

means and standard deviations of the total error scores, total aware errors scores, and percentage error detection scores were calculated. These can be seen in Table 1. Participants in the younger age group made significantly more errors overall than participants in the older age group, $t(132) = 3.48, p < .005, d = 0.60$. They were also significantly less aware of making these errors, $t(119.73) = -5.97, p < .001, d = 1.03$. To determine if there was a difference between the percentage of errors made by younger and older children, an independent t -test was performed on the error detection percentage scores. This revealed that older participants were significantly more aware of the errors they were making when compared to younger participants, $t(123.10) = -7.71, p < .001, d = 1.33$. This supports the hypothesis that children's error detection becomes more accurate as they get older.

Prediction. When asked the prediction question of the DART, twelve younger participants and three participants from the older age group gave vague answers or stated they were 'unsure' and so their data were not used in the analysis. The means and standard deviations of the prediction errors percentage scores, the actual errors percentage scores and the difference prediction percentage scores were calculated (see Table 1). It appears that younger children were less accurate at predicting how many errors they would make on the DART task, underestimating the number of errors they made more than the older age group. An independent measures t -test performed on the difference prediction percentage scores revealed significant differences between the younger and older participants' scores, $t(117) = 4.86, p < .001, d = 0.88$. Older participants were significantly more accurate at predicting how many errors they would make compared to younger participants. This supports

METACOGNITION IN CHILDREN

the hypothesis that children's prediction ability becomes more accurate as they get older.

Evaluation. For the judgment of confidence task one participant from each age group did not want to participate. The missing data for each question can be seen in Appendix H, which were not missing at random but questions participants missed out due to finding them too difficult. These did not directly affect the results as the averages were calculated according to how many questions the participants had answered.

The means and standard deviations for the average confidence judgment scores for the correct answers, incorrect answers, and the difference between these scores were calculated (see Table 1). An independent measures *t*-test was carried out on the JOC difference scores to determine if there was a significant difference between the younger and older participants' evaluation scores. This revealed a significant difference $t(124.31) = -2.48, p < .05, d = 0.43$. By looking at the means it appears older participants were more accurate at evaluating their scores.

The means and standard deviations for the JOC gamma scores by age were calculated and can be seen in Table 1. An independent *t*-test revealed significant differences for these two scores, $t(101.6) = 3.70, p < .001, d = 0.64$. By considering the means it appears that when chance is taken into consideration, younger participants' evaluative ability is more accurate than older children's. A negative gamma indicates high confidence in incorrect answers and low confidence in correct answers, and the older participants' gamma mean score was more negative than the younger group's mean score. This does not support the hypothesis that older children's evaluative ability is more accurate than younger children's ability.

METACOGNITION IN CHILDREN

Table 1.

Means and standard deviations of the error detection, prediction, and evaluation scores by age group.

Groups	N	Error Detection							
		Total errors		Total aware errors		Error detection %			
		M	SD	M	SD	M	SD		
Younger	67	29.00	16.79	4.16	4.07	18.49	20.78		
Older	67	20.12	12.49	9.25	5.67	50.86	27.38		
		Prediction							
		Prediction errors %		Actual errors %		Difference prediction %			
		M	SD	M	SD	M	SD		
Younger	55	3.25	6.57	12.22	7.19	-8.97	10.47		
Older	64	8.39	8.39	9.13	5.58	-0.74	7.99		
		Evaluation							
		JOC correct		JOC incorrect		JOC difference		JOC gamma	
		M	SD	M	SD	M	SD	M	SD
Younger	67	6.08	0.60	3.87	1.22	2.21	1.15	-0.52	0.20
Older	66	6.00	0.48	3.35	1.06	2.65	0.90	-0.62	0.11

Is there a relationship between prediction, error detection and evaluation?

Does this differ between younger and older children?

Correlations between the prediction, error detection and evaluation scores by age were calculated and can be seen in Table 2. These revealed no significant correlations between any of the variables at either age, which does not support hypothesis 2 that there is a positive relationship between the three emergent awareness abilities.

The analysis was re-run with eight outliers removed. This revealed three correlations that became significant (a table of the correlations can be seen in Appendix I). It was found that for younger children, there was a significant correlation between their error detection and evaluation scores, $r(61) = -.27, p < .05$, suggesting those that performed better at one performed worse on the other measure. There were also significant correlations between older children's prediction and error detection scores, $r(61) = .26, p < .05$, and prediction and

METACOGNITION IN CHILDREN

evaluation scores, $r(60) = .26, p < .05$. As prediction scores are more accurate the lower they are and error detection/evaluation scores are more accurate the higher they are, these correlations suggests older children who are better at prediction are worse at the other emergent awareness abilities. These findings appear to contradict hypothesis 2, as they suggest negative relationships between some emergent awareness abilities.

The r -to- z Fisher transformations revealed no significant difference between age groups for the prediction and error detection correlation coefficients, $z = -.65, p = .516$, or the error detection and evaluation correlation coefficients, $z = -1.57, p = .116$. However, there was a significant difference between the prediction and evaluation correlation coefficients, $z = -2.19, p < .05$. By looking at the correlations it appears that the relationship changes from a negative to positive one as children get older. As prediction scores are more accurate the lower they are and evaluation scores are more accurate the higher they are, it appears the relationship between the two abilities becomes weaker as children get older. This does not support hypothesis three that the relationship between the three emergent awareness abilities of prediction, error detection and evaluation will become stronger as children get older.

Re-running the analysis with eight identified outliers removed (see table A2, Appendix I) revealed the significant difference between the prediction and evaluation correlation coefficients remained, $z = -2.08, p < .05$. There was also a significant difference between the error detection and evaluation correlation coefficients, $z = -2.07, p < .05$. In younger participants those who performed better at one measure performed worse at the other, yet in older participants this changes to a non-significant positive relationship. This suggests that between the younger and older age group the relationship between error

METACOGNITION IN CHILDREN

detection and evaluation becomes stronger. Although this one correlation appears to partially support hypothesis 3, overall the lack of other significant relationships and a significant inverse one being found suggests that the relationship between the three emergent awareness abilities of prediction, error detection and evaluation do not become stronger as children get older.

Table 2

Correlations among prediction, error detection, evaluation, and metacognitive knowledge by age.

Younger participants			
	Prediction	Error detection	Evaluation
Emergent Awareness			
Prediction			
Error Detection	.12		
Evaluation	-.19	-.21	
Subjective metacognitive knowledge	-.24	-.19	-.09
Older participants			
	Prediction	Error detection	Evaluation
Emergent Awareness			
Prediction			
Error Detection	.24		
Evaluation	.22	.07	
Subjective metacognitive knowledge	.12	-.05	-.20
Difference between correlations coefficients for older vs. younger (z)			
	Prediction	Error detection	Evaluation
Emergent Awareness			
Prediction			
Error Detection	-0.65		
Evaluation	-2.19*	-1.57	
Subjective metacognitive knowledge	-1.90	-0.76	0.59

* $p < .05$.

How does children's subjective metacognitive knowledge differ in younger and older children? How do children's emergent awareness abilities relate to their subjective metacognitive knowledge in these age groups?

METACOGNITION IN CHILDREN

One participant in the older age group did not fill out the metacognitive questionnaire. The means and standard deviations of the metacognitive knowledge scores were calculated and can be seen in Table 3. An independent measures *t*-test revealed significant differences between the younger and older participants' metacognitive knowledge, $t(132) = 4.65$, $p < .001$, $d = 0.80$. Younger participants rated their metacognitive knowledge significantly higher than the older age group. This supports hypothesis four that younger children will be more confident in their subjective metacognitive knowledge than the older age group.

Table 3.

Means and standard deviations of the subjective metacognitive knowledge scores by age group.

Group	N	Subjective metacognitive knowledge	
		<i>M</i>	<i>SD</i>
Younger	68	3.98	0.50
Older	66	3.57	0.50

Correlations between subjective metacognitive knowledge, prediction, error detection and evaluation scores were calculated for each of the two age groups. These can be seen in Table 2. These revealed no significant relationships between the emergent awareness abilities of prediction, error detection and evaluation, and metacognitive knowledge at either age. When the analysis was re-run with nine identified outliers removed this revealed a significant correlation in older participants between their metacognitive skill of evaluation and metacognitive knowledge $r(61) = -.26$, $p < .05$. Older participants who performed better on the evaluation measure were worse on the measure of subjective metacognitive knowledge.

METACOGNITION IN CHILDREN

The *r*-to-*z* Fisher transformations were calculated. The between-group correlation coefficients can be seen in Table 2 and reveal no significant differences between the correlations by age group. These correlations did not change when outliers were removed (see Appendix I).

Overall the correlations do not support hypothesis five of the study that the relationships between subjective metacognitive knowledge and emergent awareness skills will change as children get older. Although one correlation (when identified outliers were removed) in older children appeared to show those with lower confidence may perform better on emergent awareness tasks of evaluation, this was within the age group, rather than in comparison to the younger age group.

Discussion

The aim of the study was to explore how children's metacognition differ in younger and older children, in particular looking at their emergent awareness abilities of prediction, error detection and evaluation. Emergent awareness was divided into these components in a model put forward by Krasny-Pacini et al. (2015), who defined these skills as those used by individuals when carrying out tasks to monitor and regulate their actions (Krasny-Pacini et al., 2015). The first hypothesis, that children's emergent awareness abilities of prediction, error detection and evaluation become more accurate as they get older, is only partially supported by the findings. Children in the older age group were more accurate at predicting how many mistakes they would make on a task and were more aware when they were making errors as the task was being carried out than younger children. However, older children appeared to be worse (when chance was taken into consideration) at evaluating the answers they had given on a task, compared to the younger age group. This final finding is not

METACOGNITION IN CHILDREN

consistent with previous research that states metacognition develops throughout childhood (Kuhn, 2000), including children's ability to evaluate their answers more accurately (Roebbers, Schmid, & Roderer, 2009).

One explanation for the finding that evaluative emergent awareness is worse in older children is that it could be due to different aspects of metacognition coming online at different times during a child's development, as suggested by Krasny-Pacini et al. (2015). Krasny-Pacini et al. (2015) believed this could be because different components of metacognition are important at different stages of children's development. Therefore, it may be that for younger children the component of their cognition that is online and developing is their evaluative emergent awareness. On the other hand, in the older age group it may be less so, due to other cognitions being more online at this age and so using more cognitive resources than this ability.

The results of the study also provided no evidence for hypothesis 2, that there will be a positive relationship between prediction, error detection and evaluation at either age. It is unknown why these were not related, but it may be that they are more strongly related to other aspects of cognitive functioning. Another explanation for these null findings comes from looking at the literature around the development of other cognitions during childhood, such as executive functions. As stated previously, metacognition is closely linked to executive functions (Fernandez-Duque et al., 2000) and may follow a similar developmental pattern (Roebbers, 2017). It has been found that for executive functions, although the different functions are interrelated, they develop separately from one another (Klenberg, Korkman, & Lahti-Nuutila, 2001). This ties in to the differentiation-dedifferentiation hypothesis: the theory that cognitions (such as executive functions) break down into distinct constructs in

METACOGNITION IN CHILDREN

childhood as they develop (Garrett, 1946) before becoming unified in adulthood (Brydges, Reid, Fox, & Anderson, 2012). This could also explain why when the analysis was re-run with outliers removed, it was found that younger children who performed better at error detection did worse on their evaluation, and for older children those that were better at prediction were worse at error detection and evaluation.

The theory of differentiation-dedifferentiation (Garrett, 1946) may also explain the lack of findings in support of hypothesis 3: relationships between children's prediction, error detection, and evaluation abilities will become stronger as a child gets older. A significant difference was found between the children's prediction and evaluation abilities, but it appeared these two abilities became more dissociated as children got older. This could be due to these cognitions breaking down into distinct constructs in childhood as they develop (Garrett, 1946). The oldest participants in the study were 12 years old and their metacognitive abilities would still be developing at this age (Weil et al., 2013).

However, it is interesting to note that (when outliers were removed) it appeared that error detection and evaluation scores became more associated. So although some components of metacognition may become dissociated as children get older (Garrett, 1946), others may become more associated. Again this could be evidence for different components of metacognition coming online at different times during a child's development (Krasny-Pacini et al., 2015).

The study also explored subjective metacognitive knowledge in younger and older children. The results appeared to show children's confidence in their metacognitive knowledge got significantly lower as they got older. This supports hypothesis four of the study that children's subjective metacognitive knowledge will be higher in the younger age group. Previous research has put forward the

METACOGNITION IN CHILDREN

theory that cognitive immaturity can be adaptive for children at particular ages (Bjorklund, 2018). Younger children may benefit from being unrealistically optimistic about their learning ability as it allows them to explore strategies for learning and makes them less fearful of failure (Bjorklund, 1997). This means they are more motivated to persist at tasks, which could result in better learning in the long-term (Bjorklund et al., 2009). The results of this study reflect Bjorklund's (1997) theory, as younger children performed worse than older children on two tasks of emergent awareness, but yet were more confident in their subjective metacognitive knowledge. This suggests that younger children are more cognitively immature, as they self-reported that they had confidence in the strategies and skills they needed for learning, but their scores on the other measures did not reflect this.

Yet when looking for significant differences between the relationships between the skills and subjective metacognitive knowledge across the two age groups, no significant differences were found. It was hypothesised that younger children would be more confident in their abilities but have lower emergent awareness skills, whereas older children would have lower confidence in their knowledge but higher skills (hypothesis 5). This would have provided further support for the theory of cognitive immaturity (Bjorklund, 1997). However, the pattern of results did not reflect this. The results suggested that in older children, those with lower confidence in their metacognitive knowledge may perform better on emergent awareness tasks of evaluation. As metacognition develops throughout childhood and adolescent (Weil et al., 2013), it could be argued this shows cognitive immaturity as children in the older age group were still relatively young. However, this result needs to be interpreted with caution

METACOGNITION IN CHILDREN

due to it only being one emergent awareness ability and the relationship was only significant when the analysis was run without outliers.

The findings provide a mixed picture of children's metacognition. Although children's predictive and error detecting emergent awareness become more accurate as children get older, this study did not find the same for children's evaluative emergent awareness. This suggests that the abilities are distinct from each other, and may also not be related to children's subjective metacognitive knowledge. Overall the findings highlight the complexity of the development of children's metacognition.

Clinical Implications

One implication of the results is the possible need for children's metacognition to be taken into consideration during clinical assessments. The findings of this study suggest that younger children have poorer emergent awareness than older children, but that they also hold beliefs that their metacognition is better at this age. It would suggest that simply asking younger children about their metacognition would not result in accurate representation of their emergent awareness ability. Therefore, it may be beneficial to develop appropriate clinical measures that objectively measure these abilities, to gain an accurate understanding of children's metacognitive ability.

It would be important to do this to inform clinical formulations and intervention work, as it has been found (although the research was completed with adult participants) that metacognition may influence the development and maintenance of mental health difficulties (Janeck et al., 2003; Papageorgiou & Wells, 2003; Wells, 2005). It would also have an impact on the ability children have to think around tasks that they are asked to complete as part of the intervention. For example, Cognitive Behaviour Therapy (CBT) has been found

METACOGNITION IN CHILDREN

to be beneficial for children as young as eight years old (Kendall, Safford, Flannery-Schroeder, & Webb, 2004) and possibly younger (Minde, Roy, Bezonsky, & Hashemi, 2010). Yet this research highlights that at age seven, children struggle to predict their performance on tasks, which is often asked of participants completing CBT, for example, when completing behavioural experiments. Therefore, if measures of metacognition were part of the assessment, then interventions may be more successful if tailored to fit with children's metacognitive abilities.

Additionally the findings of the study may be particularly relevant for children who may have diminished metacognition, or do not develop metacognition as expected, due to neurodevelopmental or health conditions (Grainger et al., 2016; Shen et al., 2011; Kizonyet et al., 2014). The findings of the study show that the different constructs of emergent awareness can be measured and that they are differentiated in childhood. As a result it would be important to consider all of the different abilities during assessments with participants with known metacognitive deficits and then tailor interventions to suit their strengths and weaknesses.

Strengths and Limitations

A strength of the study was that this appears to be the first time that three different emergent awareness abilities and metacognitive knowledge have been looked at in the same sample of participants, across two different age groups. In previous research specific abilities have been explored (Freeman et al., 2017; Schneider et al., 2000), rather than more than one aspect of metacognition. By looking at three emergent awareness abilities and metacognitive knowledge it has allowed this study to look at the relationships between these constructs within and between the two groups of participants.

METACOGNITION IN CHILDREN

Another strength of the study was the method used to measure error detection. Previous studies with children have measured this using brain electrical activity (Liotti et al., 2005), which calls into question whether participants are consciously aware when they are making a mistake, or with behavioural tasks that take a long time and so are not always feasible with larger groups of participants (Krasny-Pacini et al., 2015). The DART can measure online error detection as it asks participants to verbally indicate their awareness of making an error (O’Keeffe et al., 2007) and takes around 10 minutes to complete. It was easy to administer and children engaged well with it.

On the other hand there were limitations to the research, one of which was the other measures used. The Jr. MAI could be seen as a poor measure of metacognitive knowledge, as it was the children’s subjective opinion of their learning skills. It was assumed that those who scored higher on their measure were more confident, but it may have been that their learning strategies and skills were more accurate than those who scored lower, rather than only their confidence in them. Future research may need to consider an objective measure of metacognitive knowledge, such as a teacher-report questionnaire. As well as this, on the measure of prediction twelve younger participants and three participants from the older age group gave vague answers or stated they were ‘unsure’. Their data could not be used in the analysis for this reason. This is quite a big proportion of sample used, particularly the younger age group, suggesting that even the task of predicting may be too hard for some children.

Other limitations of the study were methodological issues. The schools were recruited through convenience sampling, meaning that it could have been particular ones that signed up to the study, for example, those with an interest in

METACOGNITION IN CHILDREN

metacognition. Also, they were all from a similar area of the country, which was considered rural, so the results may have been different if participants had been from other schools, for example, inner city schools. Another methodological limitation was that the researcher could not be blind to conditions and so may have unintentionally influenced participants. As well as this, the research looked at discrete age groups rather than across a continuum. This meant that it was more difficult to make conclusions about the trajectory changes of metacognition across age groups.

Future Research

Future research could use a longitudinal design and consider metacognition across age, rather than comparing younger and older groups of children. For example, it could carry out the same measures of metacognition with children between the ages of nine to ten and twelve to fourteen. This would enable a clearer picture to be gained about how metacognition develops and changes across childhood.

Conclusion

This study has built on previous research by providing evidence that some of children's metacognitive emergent awareness (prediction and error detection) become more accurate as children get older. However, the results did not reflect this with evaluative emergent awareness. It appears that these abilities are distinct from each other, and are not related to children's subjective metacognitive knowledge of their learning skills and strategies. They also may become more differentiated as children get older, tying in with the differentiation-dedifferentiation theory. These findings suggest care needs to be taken to consider children's metacognitive development in clinical and educational settings to ensure interventions are suited to their abilities.

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Appendix A

The Metacognitive Assessment Inventories (Version A & B)

The Metacognitive Assessment Inventory: Version A

We are interested in what learners do when they study. Please read the following sentences and circle the answer that relates to you and the way you are when you are doing school work or home work. Please answer as honestly as possible.

- | | | | |
|---|-------|-----------|--------|
| 1. I know when I understand something. | Never | Sometimes | Always |
| 2. I can make myself learn when I need to. | Never | Sometimes | Always |
| 3. I try to use ways of studying that have worked for me before. | Never | Sometimes | Always |
| 4. I know what the teacher expects me to learn. | Never | Sometimes | Always |
| 5. I learn best when I already know something about the topic. | Never | Sometimes | Always |
| 6. I draw pictures or diagrams to help me understand while learning. | Never | Sometimes | Always |
| 7. When I am done with my schoolwork, I ask myself if I learned what I wanted to learn. | Never | Sometimes | Always |
| 8. I think of several ways to solve a problem and then choose the best one. | Never | Sometimes | Always |
| 9. I think about what I need to learn before I start working | Never | Sometimes | Always |
| 10. I ask myself how well I am doing while I am learning something new. | Never | Sometimes | Always |
| 11. I really pay attention to important information. | Never | Sometimes | Always |
| 12. I learn more when I am interested in the topic. | Never | Sometimes | Always |

The Metacognitive Assessment Inventory: Version B

We are interested in what learners do when they study. Please read the following sentences and circle the answer that relates to you and the way you are when you are doing school work or home work. Please answer as honestly as possible.

1 = Never 2 = Seldom 3 = Sometimes 4 = Often 5 = Always

1. I know when I understand something.	1	2	3	4	5
2. I can make myself learn when I need to.	1	2	3	4	5
3. I try to use ways of studying that have worked for me before.	1	2	3	4	5
4. I know what the teacher expects me to learn.	1	2	3	4	5
5. I learn best when I already know something about the topic.	1	2	3	4	5
6. I draw pictures or diagrams to help me understand while learning.	1	2	3	4	5
7. When I am done with my schoolwork, I ask myself if I learned what I wanted to learn.	1	2	3	4	5
8. I think of several ways to solve a problem and then choose the best one.	1	2	3	4	5
9. I think about what I need to learn before I start working	1	2	3	4	5
10. I ask myself how well I am doing while I am learning something new.	1	2	3	4	5
11. I really pay attention to important information.	1	2	3	4	5
12. I learn more when I am interested in the topic.	1	2	3	4	5
13. I use my learning strengths to make up for my weaknesses.	1	2	3	4	5
14. I use different learning strategies depending on the task	1	2	3	4	5
15. I occasionally check to make sure I'll get my work done on time.	1	2	3	4	5
16. I sometimes use learning strategies without thinking.	1	2	3	4	5
17. I ask myself if there was an easier way to do things after I finish a task.	1	2	3	4	5
18. I decide what I need to get done before I start a task.	1	2	3	4	5

Appendix B

Judgment of Confidence Task

<p>11. What do kangaroos eat?</p>	<p>On a scale of 1-7, how confident are you that your answer is correct?</p> <p><i>Extremely</i> <i>Extremely</i> <i>unsure</i> <i>sure</i></p> <p>1 2 3 4 5 6 7</p>
<p>12. What are baby kangaroos the size of when they are born?</p>	<p>On a scale of 1-7, how confident are you that your answer is correct?</p> <p><i>Extremely</i> <i>Extremely</i> <i>unsure</i> <i>sure</i></p> <p>1 2 3 4 5 6 7</p>
<p>13. How far can a kangaroo jump (in feet)?</p>	<p>On a scale of 1-7, how confident are you that your answer is correct?</p> <p><i>Extremely</i> <i>Extremely</i> <i>unsure</i> <i>sure</i></p> <p>1 2 3 4 5 6 7</p>
<p>14. What is the Latin species name for the Eastern Gray Kangaroo?</p>	<p>On a scale of 1-7, how confident are you that your answer is correct?</p> <p><i>Extremely</i> <i>Extremely</i> <i>unsure</i> <i>sure</i></p> <p>1 2 3 4 5 6 7</p>
<p>15. What does their Latin species name mean?</p>	<p>On a scale of 1-7, how confident are you that your answer is correct?</p> <p><i>Extremely</i> <i>Extremely</i> <i>unsure</i> <i>sure</i></p> <p>1 2 3 4 5 6 7</p>
<p>16. What family do kangaroos belong to?</p>	<p>On a scale of 1-7, how confident are you that your answer is correct?</p> <p><i>Extremely</i> <i>Extremely</i> <i>unsure</i> <i>sure</i></p> <p>1 2 3 4 5 6 7</p>

Appendix C

Ethics Approval Letter



CLES – Psychology
Psychology
College of Life and Environmental Sciences
University of Exeter
Washington Singer Building
Perry Road
Exeter
EX4 4QG
Web: www.exeter.ac.uk

CLES – Psychology Ethics Committee

Dear Rebecca Jenkin

Ethics application - eCLESPsy000076

A research study exploring how children's online and offline awareness abilities change and develop by age.

Your project has been reviewed by the CLES – Psychology Ethics Committee and has received a Favourable opinion.

The Committee has made the following comments about your application:

- Please view your application at <https://eethics.exeter.ac.uk/CLESPsy/> to see comments in full. If you have received a Favourable with conditions, Provisional or unfavourable outcome you are required to re-submit for full review and/or confirm that committee comments have been addressed before you begin your research.

If you have any further queries, please contact your Ethics Officer.

Yours sincerely

Date: 28/04/2019

CLES – Psychology Ethics Committee

Appendix D

Information Leaflet for Schools

**Information Leaflet for Schools**

(Version 2: June 2018)

Children's Metacognition:

Are older children more aware of making mistakes when carrying out a task compared to younger children? Do they also have more awareness about how they learn best?

Thank you for considering our request to conduct research into children's metacognition with children in your school. We're very happy to answer any questions you have about the project and have provided our contact details on the next page.

Introduction

My name is Becky Jenkin and I am a student based at the University of Exeter. I am currently completing my training to become a Clinical Psychologist. As part of this I am carrying out a research project, about children's metacognition: how they think about their thinking. I am looking at whether children become more aware at noticing when they make mistakes on a task as they get older. It is being carried out with children between the ages of 7 – 14 years old. The project has been reviewed by the University of Exeter Psychology Ethics Committee.

Why has my school been approached?

We are approaching schools in XXXX to see if they would be interested in taking part in the study. We are doing this by emailing schools.

What will happen during the study?

Children will be taken out of class one at a time, and asked to complete some activities with Becky. This will take approximately 45 minutes per child. All children will be asked to complete activities looking at their abilities to predict and evaluate what they are carrying out. There will also be an activity that looks at their ability to detect errors. The answers children give during these activities will be recorded by Becky. Overall this data should teach us more about how children think about their own thinking style.

The tasks the children complete are set up as **puzzles and games**, which are **suited for their age**. They are **not being tested** on their overall intelligence – we are only comparing the results of the measures by age.

Every child can decide not to take part, or choose to stop the study at any point. This will be told to them at the start of the study.

Consent that is required

For the research to go ahead we require consent from the headteacher and teachers (of the classes taking part) in the school.

Also parents/legal guardians of all the children in the class will be approached for permission for their child to take part in the study. With your permission, a leaflet about the study will be sent via the school to the parents with an opt-in form, which they can fill in and return to the school office should they **consent** to their child taking part.

Can the school, individual children or teachers change our minds and withdraw from the study at any time?

Yes. The school, children and teachers are free to withdraw from the study at any point, without giving a reason, and without your legal rights being affected.

What are the benefits of taking part?

This research fits within the science curriculum (working scientifically), teaching children about scientific attitudes and experimental skills and investigations.

What if I do not want my school/class to take part?

You do not need to take part in the study, it is completely your decision whether to take part or not.

Confidentiality and security of Information

All information that we collect about each child will be kept confidential, unless doing so would put anyone at risk of serious harm. Information gathered will be anonymised. In accordance with the research ethical guidance of the University of Exeter Psychology Ethics Committee the information collected in the study will be used for research purposes only and stored securely, in a locked filing cabinet or on a password protected laptop. All data will be destroyed 5 years after publication.

The data collected during the study may be looked at by members of the research team at the University of Exeter. We will aim to publish the findings from this study so other people working in this area can learn about our work. All schools and children will remain completely anonymous in any write-up, and will not be identified in any publication. Anonymised data may also be shared with other researchers in the future.

The University of Exeter processes personal data for the purposes of carrying out research in the public interest. The University will endeavour to be transparent about its processing of your personal data and this information sheet should provide a clear explanation of this. If you do have any queries about the University's processing of your personal data that cannot be resolved by the research team, further information may be obtained from the University's Data Protection Officer by emailing dataprotection@exeter.ac.uk or at www.exeter.ac.uk/dataprotection

Time Commitment

Time commitment will differ depending on what is most suitable for each school. We're very happy to discuss the best requirements for your school.

Any questions?

If you have any questions about this study, either now or in the future, please contact:

Becky Jenkin

DClinPsy student

rebecca.jenkin@exeter.ac.uk

Jenny Limond

Senior lecturer at the University of Exeter
(Supervisor on this project)

J.Limond@exeter.ac.uk

Complaints

If you have any complaints about the way in which this study has been carried out please contact the Chair of the University of Exeter Psychology Ethics Committee:-

Lisa Leaver

Chair, UoE Psychology Ethics Committee

l.a.leaver@ex.ac.uk

Thank you very much for considering this request.

Appendix E

Headteacher and Teacher Consent Forms

**Headteacher Consent Form**

(Version 2: June 2018)

Children's Metacognition:

Are older children more aware of making mistakes when carrying out a task compared to younger children? Do they also have more awareness about how they learn best?

Name of researcher: Becky Jenkin

I have read the information leaflet (version 2: June 2018) for the above study. I have had the opportunity to consider the information, ask questions, and have had these answered satisfactorily. I understand that I am free to request any further information at any stage.

I know that: *(please circle Yes / No)*

- | | | |
|----|--|----------|
| 1. | this school's participation is entirely voluntary; | Yes / No |
| 2. | the school is free to withdraw at any time without giving any reason and without mine or the school's legal rights being affected; | Yes / No |
| 3. | I agree to let the researcher come into the school and collect data from the children, subject to her obtaining consent from the teachers of those classes that will be affected; | Yes / No |
| 4. | I understand that the research will be taking place in a room designated to the researcher by the school, and will involve each child being taken out of class for approximately 45 minutes; | Yes / No |
| 5. | I understand that any teacher, parent/carer or child can decide not to take part or withdraw from the study and that this will result in no negative consequences. | Yes / No |
| 6. | the data that is collected will remain in secure storage for up to five years after the research has been completed and be written up as part of a DClinPsy student's coursework; | Yes / No |
| 7. | I understand that relevant sections of the data collected during the study may be looked at by members of the research team. | Yes/No |
| 8. | The results of the study may be published but both the school's anonymity and the children's anonymity will be preserved. Anonymised data may also be shared with other researchers in the future. | Yes / No |

I agree for this school to take part in the study.

Name of school: _____

Printed name of Headteacher

Signature

Date

Printed name of Researcher

Signature

Date

2 copies: 1 for Headteacher, 1 for Researcher



Teacher Consent Form
(Version 2: June 2018)

Children’s Metacognition:

Are older children more aware of making mistakes when carrying out a task compared to younger children? Do they also have more awareness about how they learn best?

Name of researcher: Becky Jenkin

I have read the information leaflet (version 2: June 2018) for the above study. I have had the opportunity to consider the information, ask questions, and have had these answered satisfactorily. I understand that I am free to request any further information at any stage.

I know that: *(please circle Yes / No)*

- | | | |
|----|--|----------|
| 1. | My class’s participation is entirely voluntary; | Yes / No |
| 2. | I am free to withdraw at any time without giving any reason and without mine or the school’s legal rights being affected; | Yes / No |
| 3. | I understand that the research will be taking place in a room designated to the researcher by the school, and will involve each child being taken out of class for approximately 45 minutes each; | Yes / No |
| 4. | I understand that any teacher, parent/carer or child can decide not to take part or withdraw from the study and that this will result in no negative consequences. | Yes / No |
| 5. | the data that is collected will remain in secure storage for up to five years after the research has been completed and be written up as part of a DClInPsy student’s coursework; | Yes / No |
| 6. | I understand that relevant sections of the data collected during the study may be looked at by members of the research team. | Yes/No |
| 7. | The results of the study may be published but both the school’s anonymity and the children’s anonymity will be preserved. Anonymised data may also be shared with other researchers in the future. | Yes / No |

I agree for my class to take part in the study.

Name of school: _____

Printed name of Teacher	Signature	Date

Printed name of Researcher	Signature	Date

2 copies: 1 for teacher, 1 for Researcher

Appendix F

Information Leaflet and Consent Form for Parents/Carers



Information Leaflet for Parents/Carers

(Version 2: June 2018)

Children's Metacognition:

Are older children more aware of making mistakes when carrying out a task compared to younger children? Do they also have more awareness about how they learn best?

Introduction

My name is Becky Jenkin and I am a student based at the University of Exeter. I am currently completing my training to become a Clinical Psychologist. As part of this I am carrying out a research project, about children's metacognition, how they think about their thinking. It is looking at whether children become more aware at noticing when they make mistakes on a task as they get older. The project has been reviewed by the University of Exeter Psychology Ethics Committee.

Why have I been approached?

We have been approaching schools in XXXX to see if they would be interested in taking part in the study. Your child's school has agreed to help with my research. **This information leaflet has been sent to ALL children in your child's class.** The school has not given us any information about any child, and they are sending you this leaflet on our behalf.

What will happen during the study?

Your child will be asked to some activities with Becky, which will take about 45 minutes. This will happen during school time. This is happening with children between the ages of 7 and 14 years old. The scores will be compared to see how children's thinking changes as they get older.

All children will be asked to complete activities looking at their abilities to predict and evaluate what they are carrying out. There will also be an activity that looks at their ability to detect errors. The answers they give during these activities will be recorded by Becky. Overall this data should teach us more about how children think about their own thinking style.

The tasks the children complete are set up as **puzzles and games**, which are **suitable for their age**. They are **not being tested** on their overall intelligence – we are only comparing the results of the measures by age.

Your child can decide not to take part, or choose to stop the study at any point. This will be told to them at the start of the study.

Permission that is required

The headteacher at your child's school, and also your child's teacher, have given permission for the study to go ahead. I am contacting all parents in your child's class to see if they would be willing to let their child take part. Whether your child does or not is entirely up to you.



If you are happy for your child to take part then **please sign the form that comes with this leaflet, and hand it back into the reception desk at your school.** This has to be done by **DATE**.



If you do not want your child to take part you do not need to do anything.
Children will not take part in the research without parent/carer permission.

Can the school, individual children or teachers change our minds and withdraw from the study?

Yes. The school, children and teachers are free to withdraw from the study at any point, without giving a reason, and without legal rights being affected.

What are the benefits of taking part?

This research fits within the science curriculum (working scientifically), teaching children about scientific attitudes and experimental skills and investigations.

What if I do not want my child to take part?

You do not need to do anything, as parent/carer consent is required for every child who takes part in the study.

Confidentiality and security of Information

All information that we collect about each child will be kept confidential and anonymous, unless doing so would put anyone at risk of serious harm. In accordance with the research ethical guidance of the University of Exeter Psychology Ethics Committee the information collected in the study will be used for research purposes only and stored securely, in a locked filing cabinet or on a password protected laptop. All data will be treated anonymously and destroyed 5 years after publication.

The data collected during the study may be looked at by members of the research team. We will aim to publish the findings from this study so other people working in this area can learn about our work. All schools and children taking part will be completely anonymous in the study, and will not be identified in any publication. Anonymised data may also be shared with other researchers in the future.

The University of Exeter processes personal data for the purposes of carrying out research in the public interest. The University will endeavour to be transparent about its processing of your personal data and this information sheet should provide a clear explanation of this. If you do have any queries about the University's processing of your personal data that cannot be resolved by the research team, further information may be obtained from the University's Data Protection Officer by emailing dataprotection@exeter.ac.uk or at www.exeter.ac.uk/dataprotection

Any questions?

If you have any questions about this study, either now or in the future, please contact:

Becky Jenkin

DClinPsy student

rebecca.jenkin@exeter.ac.uk

Jenny Limond

Senior lecturer at the University of Exeter
(Supervisor on this project)

J.Limond@exeter.ac.uk

Complaints

If you have any complaints about the way in which this study has been carried out please contact the Chair of the University of Exeter Psychology Ethics Committee:-

Lisa Leaver

Chair, UoE Psychology Ethics Committee

l.a.leaver@ex.ac.uk

Thank you very much for considering this request.



Consent Form
(Version 2: June 2018)

Children's Metacognition:
Are older children more aware of making mistakes when carrying out a task compared to younger children? Do they also have more awareness about how they learn best?

Name of researcher: Becky Jenkin

Please only fill this out if you are happy for your child to take part in the study, and so give your consent. If you **do not give consent for them to take part you do not need to do anything; children will not take part in the study without parent/carer consent.**

1. I confirm that I have read and understand the information leaflet (**version 2: June 2018**) for the above study. I have had the opportunity to consider the information, ask questions by emailing the researchers, and have had these answered satisfactorily.
2. I understand that my child's participation is voluntary, and that I am free to withdraw my child from the study at any time without giving any reason and without my legal rights being affected.
3. I understand that the research will be taking place in a room designated to the researcher by the school, and will involve each child being taken out of class for approximately 45 minutes;
4. I understand that answers my child gives during the study will be recorded, and relevant sections of this data may be looked at by members of the research team.
5. I understand that the data collected will remain in secure storage for up to five years after the research has been completed and be written up as part of a DClinPsy student's coursework;
6. I understand that the results of the study may be published but both the school's anonymity and the children's anonymity will be preserved. Anonymised data may also be shared with other researchers in the future.
7. I understand that the researcher has gained consent from the headteacher and class teacher to carry out this study.

I GIVE CONSENT for my child to take part in the above study.

Name of Child:

Your Name

Date

Signature

Please return this form to (TEACHER) by DATE
Thank you very much

Appendix G

Child Information Sheet, Consent Form and Debrief Sheet

**Becky's research study: Child Information sheet**

My name is Becky and I am working with your school. I want to know more about children's thinking.

In particular I am interested in what children think about an activity before, during, and after they complete the activity.

For the next 45 minutes you will be doing a few activities with me. I will be recording the answers you give me.

Once I have completed the study with all children I will look at all of the answers together, to learn more about children's thinking.

You do not have to take part.

You can stop at any point, and ask me to not use the answers you have given. No one but me will know the answers you give me.

The only time I would pass information on about you would be if you tell me something I think may be harming you or someone else. If this were to happen I would tell a teacher.

Please feel free to ask if you have any questions now.



Becky's research: Child assent form

I have read the information sheet about the study, and I understand it.

All my questions have been answered.

I know why I am doing these activities.

I know that I can decide not to take part at any point, and ask for my answers not to be used.

I know that the answers I give cannot be linked to me.

I understand all this and so agree to take part.

.....
(Your name)

.....
(Name of child)

.....
(Number)

.....
(Name of researcher)

.....
(Date)



Becky's research study: Debrief sheet

Participant number:

Thank you for taking part in my research study. The study was interested in children's thinking when completing different activities.

It has involved doing a few activities with me. I recorded the answers you gave me.

If you have decided you do not want me to use the answers you gave me as part of the research then please tell me. Or you can tell your teacher.

If you decide that you do not want me to use the answers you gave me in the future, please tell your teacher and give them your participant number (at the top of the page) by:

Please feel free to ask any questions you have.

Appendix H

Missing Data for JOC Questions

Table A1.

The number (N) of missing data points for each of the Judgment Of Confidence (JOC) questions.

JOC Question	Missing data (N)
1	0
2	0
3	0
4	0
5	3
6	0
7	23
8	17
9	2
10	4
11	1
12	0
13	0
14	77
15	28
16	27

Appendix I

Outlier Analysis

Table A2.

Correlations among prediction, error detection, evaluation, and metacognitive knowledge by age with outliers removed.

Younger participants			
	Prediction	Error detection	Evaluation
Emergent Awareness			
Prediction			
Error Detection	.08		
Evaluation	-.14	-.27*	
Subjective metacognitive knowledge	-.18	-.17	-.11
Older participants			
	Prediction	Error detection	Evaluation
Emergent Awareness			
Prediction			
Error Detection	.26*		
Evaluation	.26*	.10	
Subjective metacognitive knowledge	.04	-.05	-.26*
Difference between correlations coefficients for older vs. younger (z)			
	Prediction	Error detection	Evaluation
Emergent Awareness			
Prediction			
Error Detection	-.94		
Evaluation	-2.08*	-2.07*	
Subjective metacognitive knowledge	-1.17	-.64	.85

* $p < .05$.

Appendix J

Dissemination Statement

I presented an outline of the research and preliminary findings to teachers at a Secondary School (where I collected the data) in November 2018, as part of a teacher's evening on metacognition.

This thesis will be submitted as part of the requirements of the doctoral programme. I will also be completing a presentation on the research in June 2019 at the University of Exeter, to Trainee Clinical Psychologists and staff.

Schools who took part in the study will receive an information leaflet outlining the research findings. I will also offer to go in to these schools to give presentations on the research to teachers and other interested parties.

I intend on submitting a research paper for publication in *Consciousness and Cognition*, a peer-reviewed journal.

Appendix K

Preparation and Submission Requirements for *Consciousness and Cognition*

Consciousness and Cognition, An International Journal, provides a forum for a natural science approach to the issues of consciousness, voluntary control, and self. The journal features empirical research (in the form of articles) and theoretical reviews. The journal aims to be both scientifically rigorous and open to novel contributions.

Guide for Authors

The file should be saved in the native format of the wordprocessor used. The text should be in single-spaced in single-column format. Keep the layout of the text as simple as possible. Most formatting codes will be removed and replaced on processing the article. In particular, do not use the wordprocessor's options to justify text or to hyphenate words. However, do use bold face, italics, subscripts, superscripts etc. When preparing tables, if you are using a table grid, use only one grid for each individual table and not a grid for each row. If no grid is used, use tabs, not spaces, to align columns. The electronic text should be prepared in a way very similar to that of conventional manuscripts (see also the Guide to Publishing with Elsevier:

<https://www.elsevier.com/guidepublication>). Note that source files of figures, tables and text graphics will be required whether or not you embed your figures in the text. See also the section on Electronic artwork.

Article structure

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.

Introduction

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

Material and methods

Provide sufficient details to allow the work to be reproduced by an independent researcher. Methods that are already published should be summarized, and indicated by a reference. If quoting directly from a previously published method, use quotation marks and also cite the source. Any modifications to existing methods should also be described.

Results

Results should be clear and concise.

Discussion

This should explore the significance of the results of the work, not repeat them. A combined Results and Discussion section is often appropriate. Avoid extensive citations and discussion of published literature.

Conclusions

The main conclusions of the study may be presented in a short Conclusions section, which may stand alone or form a subsection of a Discussion or Results and Discussion section.

Appendices

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.

Essential title page information

- Title. Concise and informative. Titles are often used in information-retrieval systems. Avoid abbreviations and formulae where possible.
- Author names and affiliations. Please clearly indicate the given name(s) and family name(s) of each author and check that all names are accurately spelled. You can add your name between parentheses in your own script behind the English transliteration. Present the authors' affiliation addresses (where the actual work was done) below the names. Indicate all affiliations with a lower-case superscript letter immediately after the author's name and in front of the appropriate address. Provide the full postal address of each affiliation, including the country name and, if available, the e-mail address of each author.
- Corresponding author. Clearly indicate who will handle correspondence at all stages of refereeing and publication, also post-publication

Abstract

A concise and factual abstract is required. The abstract should state briefly the purpose of the research, the principal results and major conclusions. An abstract is often presented separately from the article, so it must be able to stand alone. For this reason, References should be avoided, but if essential, then cite the author(s) and year(s). Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.