The appropriateness of the Tower of LondonDX to measure executive skills in children during neuropsychological assessment: a rapid review

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS……..i

SUMMARY.....ii

OPSOMMING……..v

PREFACE……..viii

PERMISSION TO SUBMIT ARTICLE FOR EXAMINATION PURPOSES……..x

DECLARATION BY RESEARCHER…….xi

GUIDELINES FOR AUTHORS.....xii

1 LITERATURE REVIEW.....1

Introduction.....1

Clarification of concepts.....1

Executive function (EF).....1

Children.....2

Tower of London.....2

Rapid review.....2

Neuropsychological assessment.....3

Literature review.....4

Appropriateness of neuropsychological assessments in the South African context.....4

Executive skills domains in children.....6

The development of executive skills.....7

The importance of executive skills and the impact of executive function deficits.....10

Neuro-anatomy of executive functions.....12

Neuropsychological assessment of executive skills.....13

The Tower of London-Drexel Version (TOL^{DX}).....14

The TOL^{DX} administration procedure.....16

Scoring the TOL^{DX}.....16

The TOL^{DX} as a suitable measure of executive skills.....17

TOL^{DX} norms.....18

Current gaps in TOL^{DX} research.....18

The suitability of the TOL^{DX} in the South African context.....19

Summary and conclusion.....20

References.....21

2 ARTICLE.....31

Title Page of Manuscript.....31

Abstract.....33

The appropriateness of the Tower of London^{DX} to measure executive skills in children during neuropsychological assessment: a rapid review.....34

The effects of executive skills impairment.....35

Neuropsychological assessments and executive skills in children.....35

The Tower of London....37

Aims and objectives....39

Methodology....39

Research design....39

Data generation....40

Data analysis....43

Scientific rigour....47

Ethical considerations....47

Results....48

Evidence that the TOL^{DX} has diagnostic/clinical utility....48

Total Move Score....48

Total Initiation Time....49

Total Execution Time....49

Total Time Violations....50

Total Rule Violations....50

Classification accuracy....50

Measuring different aspects of executive functioning....51

Evidence that the TOL^{DX} is a valid and reliable measure in children....51

Reliability....51

Validity....52

Evidence that the TOL^{DX} is able to differentiate between different age levels....52

Total Move Score....52

Total Rule Violations....52
Total Time Violations....52
Limitations of the TOL^{DX}....53
Discussion....54
Conclusion....59
Recommendations....59
References....61
3 CRITICAL REFLECTION....68
Conclusion....71
APPENDIX A: CRITICAL APPRAISAL....72
APPENDIX B: DECLARATION BY LANGUAGE EDITOR....73

LIST OF FIGURES

Figure 1. Search strategy results..42

LIST OF TABLES

Table 1. *Final Keywords*.....41

Table 2. *Data Extraction*.....44

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Summary

The aim of the current study was to conduct a rapid review focused on the existing literature to explore the appropriateness of the TOL^{DX} as a measure of executive functioning in children. The research findings of existing scientific literature on the use of the TOL^{DX} as a neuropsychological assessment of executive skills in children were synthesised.

A total of four articles (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Marton, 2008; Solanto et al., 2007) were identified as complying with all the search terms and the eligibility criteria of this study. Four main themes were identified from the analysis of these articles, namely: (1) evidence that the TOL^{DX} has diagnostic/clinical utility; (2) evidence that the TOL^{DX} is a valid and reliable measure in children; (3) evidence that the TOL^{DX} is able to differentiate among age levels; and (4) limitations of the TOL^{DX}.

The picture emerged of the TOL^{DX} as a valid and reliable measure of executive functioning in children and appears to have important implications for clinical and diagnostic utility. This was made clear through the consistently superior scores of normally developing children across all scoring variables on the TOL^{DX} contrasted with clinical children. This indicated that the TOL^{DX} demonstrated acceptable and appropriate classification accuracy and clinical utility, particularly when used in conjunction with other neuropsychological measures to optimise diagnostic accuracy. The clinical groups appeared to perform more poorly in observational measures of motor impulsivity while performing cognitive tasks, as well as in visual-spatial working memory when engaged in planning. By assessing executive concept formation, executive problem-solving, and prospective memory, this measure provides supplementary information on individual functioning.

The TOL^{DX} appears to be a valid and reliable measure of executive functioning, specifically executive planning and problem-solving abilities in children. The TOL^{DX} appears to offer reliable and valid diagnostic information.

The TOL^{DX} appears to be sensitive and capable of differentiating among different age groups in children. The executive planning performance of older children is characterised by greater accuracy, efficiency, and speed of performance. The TOL^{DX} implicates greater executive efficiency as a primary determinant of improved performance on the task

Some important limitations of the TOL^{DX} were brought to light. To date, no reliability studies with normal children could be located, and consequently comparable levels of stability on the TOL^{DX} could not be determined. The samples used did not covary for comorbidities, they were not demographically diverse, the number of female participants was too few to compute gender effects, and samples sizes were relatively small.

This study presents the findings and thus the implications thereof regarding the necessity for standardisation and normative studies to be conducted in other countries such as South Africa, where the level and quality of education among children vary greatly. The findings highlight the gaps in current research. This is of particular importance and use for all psychologists who engage with neuropsychological practice in South Africa, as well as for teachers and parents who have to make adjustments for the needs of these children during learner support.

Some of the key limitations of the present study were that only four articles complied with all the search terms and eligibility criteria. Generalising the findings of this study is therefore not possible. Also, since no studies done in South Africa could be included, it is difficult to form a clear picture of the appropriateness of the TOL^{DX} in the South African context and to make appropriate recommendations in this regard. This study was based on studies of relatively small sample size. As such, it does not represent all data and literature on executive functioning measures and assessments.

Keywords: children, executive functions, executive skills, neuropsychological assessment, rapid review, Tower of London^{DX} (TOL^{DX})

Opsomming

Die doel van hierdie bondige sistematiese analise oorsigstudie was om bestaande literatuur, ter bepaling van die toepaslikheid van die Tower of London (TOL^{DX}) as meetinstrument van uitvoerende funksies in kinders, te ondersoek. ‘n Sintese van die navorsingsbevindinge in bestaande literatuur oor die wetenskaplike gebruik van die TOL^{DX} as neurosielkundige meetinstrument vir uitvoerende funksies in spesifiek kinders, is gemaak.

‘n Totaal van vier artikels (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Marton, 2008; Solanto et al., 2007), wat aan alle soektog- en insluitingskriteria voldoen, is uitgekies. Die bondige sistematiese analise van die gekose artikels het tot vier hooftemas aanleiding gegee, naamlik: (1) bewys dat die TOL^{DX} oor diagnostiese en kliniese bruikbaarheid beskik; (2) bewys dat die TOL^{DX} ‘n geldige en betroubare meetinstument vir uitvoerende funksies in kinders is; (3) bewys dat die TOL^{DX} effektief tussen verskillende ouderdomsgroepe kan differensieer; en (4) beperkinge van die TOL^{DX}.

Die TOL^{DX} het as ‘n geldige en betroubare meetinstrument van uitvoerende funksies in die steekproef popualsie vertoon en blyk belangrike kliniese en diagnostiese gebruik te hê. Hierdie gevolgtrekking het duidelik geblyk uit die volgehoue superieure tellings van ”normaal-ontwikkelende” kinders, regoor alle nasientellings van die TOL^{DX} heen, in teenstelling met dié van kinders met kliniese diagnoses soos Aandagtekort Hiperaktiwiteit Sindroom (ATHV), Traumatiese breinbeserings (TBB) en Taalversteurings. Hulle tellings het daarop gedui dat die TOL^{DX} oor aanvaarbare en toepaslike klassifikasie akkuraatheid en kliniese gebruikswaarde beskik, veral wanneer dit in samehang met ander neurosielkundige meetinstrumente gebruik word om diagnostiese akkuraatheid te optimaliseer. Dit het geblyk dat die kliniese groepe tydens kliniese observasie metings swakker gevaar het wat betref motoriese impulsiwiteit, veral tydens die uitvoering van kognitiewe take, asook met visueel-ruimtelike geheue tydens beplanningstake. Deurdat hierdie meetinstrument uitvoerende

konsepvorming, probleemoplossing en prospektiewe geheue (vooruitbeplanning) meet, verskaf dit waardevolle bykomende inligting oor ‘n individu se uitvoerende funksionering. Die TOL^{DX} blyk dus ‘n geldige en betroubare meetinstrument van uitvoerende funskionering in kinders te wees, veral wat hulle uitvoerende beplanning en probleemoplossingsvermoëns aanbetref. Die TOL^{DX} blyk gevolglik ook geldige en betroubare diagnostiese inligting te verskaf.

Voorts vertoon die TOL^{DX} sensitief ten opsigte van ouderdomsdifferensiasie in verskillende oudersdomgroepe van kinders te wees. Die uitvoerende beplanningsprestasie van ouer kinders word gekenmerk deur groter akkuraatheid, effektiwiteit en werkspoed as dié van jonger kinders. Verbetering in uitvoerende taakprestasie op die TOL^{DX} kan dus as primêre determinant van verbetering in uitvoerende effektiwiteit beskou word.

Daar is egter ook belangrike leemtes ten opsigte van navorsing betreffende die TOL^{DX} geidentifiseer. Tot op hede, kon daar nie betroubaarheidstudies met “normaal-ontwikkelende” kinders gevind word nie, en gevolglik kon vergelykbare vlakke van stabiliteit van prestasie op die TOL^{DX} nie bepaal word nie. Die steekproewe van bestaande studies kon nie kovariansie analises van komorbiede toestande doen nie, hulle was nie demografies divers nie, die aantal vroulike deelnemers was te min om byvoorbeeld geslagsverskille te bepaal, en die populasiegroep was oor die algemeen nogal klein.

Hierdie studie hou die bevindinge, asook die implikasies daarvan betreffende die noodsaaklikheid van standaardisasie en normatiewe studies in ‘n land soos Suid-Afrika voor – veral waar die kwaliteit van onderwys tussen kinders grootliks verskil. Die bevindige beklemtoon die leemtes in huidige navorsing en behoort van nut te wees vir alle sielkundiges wat neurosielkundige werk in die Suid-Afrikaanse konteks doen, asook vir ouers en onderwysers wat aanpassings in die klaskamerkonteks ter wille van leerderondersteuning moet maak.

Van die belangrikste beperkinge van hierdie bondige oosrigstudie is die klein aantal artikels, en gevolglik ‘n klein steekproef, wat op grond van die gekose soektogterme en insluitingskriteria benut kon word. Dit is dus nie moontlik om die bevindinge van hierdie oorsig te veralgemeen nie. Voorts, aangesien daar geen bestaande Suid-Afrikaanse studies was nie, was dit moeilk om ‘n duidelike idee oor die toepaslikheid van die TOL^{DX} in die Suid-Afrikaanse konteks te vorm en om aanbevelings in dié verband te maak. Die leemtes bevestig egter die noodsaaklikheid van Suid-Afrikaanse studies in hierdie verband.

Sleutelterme: kinders, uitvoerende funksies, uitvoerende vaardighede, neurosielkundige evaluasie, bondige oorsigstudie, Tower of London^{DX} (TOL^{DX}).

Preface

This mini-dissertation forms part of the requirements for the completion of the degree Master of Science in Clinical Psychology at the Potchefstroom Campus of the North-West University. It has been prepared in article format (manuscript to be submitted for publication), contains three chapters and complies with the requirements of the North-West University given in rule A.4.4.2.9.

Chapter 1 includes an in-depth literature review that aims to present the reader with background information and the defining concepts that are relevant to this study. Chapter 2 presents the manuscript that will be submitted to the *South African Journal of Psychology* for possible publication. The manuscript itself includes a short introduction, the aims of the study and the methodology followed, as well as the findings of the study and a discussion of and conclusion on these. Finally, Chapter 3 presents a critical reflection by the researcher on the research process.

The text of Chapter 2 has been compiled in accordance with the authors' guidelines set out by the *South African Journal of Psychology,* with the goal of possible submission for publication.

The style of the manuscript and the reference list is in accordance with the specifications of the APA (American Psychological Association, 6th Edition) publication guidelines for the purpose of examination. Where the journal specifications differ from the APA publication guidelines, the appropriate amendments will be made before submission for publication.

For the purpose of examination, the pages will be numbered chronologically from the table of contents page, ending with the appendices.

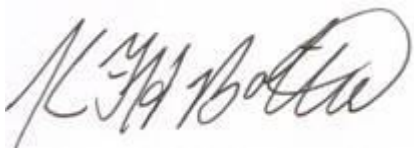
A language practitioner did the language editing of this mini-dissertation (see Appendix B).

Consent for the submission of this mini-dissertation for examination purposes (in partial fulfilment of the requirements for the Master of Science Degree in Clinical Psychology) has been provided by the research supervisors, Dr Doret Kirsten and Prof. Karel Botha.

Lastly, this mini-dissertation was submitted to Turn-it-in, which established that its content falls within the norms of acceptability in respect of plagiarism.

Permission to submit article for examination purposes

We, the undersigned and supervisors of this study and co-authors of the journal manuscript, hereby declare that the mini-dissertation entitled, *The appropriateness of the Tower of London^{DX} to measure executive skills in children during neuropsychological assessment: a rapid review*, written by Tahnita Monteiro, does reflect the research regarding the subject matter and is her own work. We hereby grant permission that she may submit the article for examination purposes and we confirm that the dissertation submitted is in partial fulfilment of the requirements for the degree Master of Science in Clinical Psychology at the Potchefstroom Campus of the North-West University. The article may also be sent to the *South African Journal of Psychology* for publication purposes.



Dr Doret Kirsten

Research supervisor

Prof. Karel Botha

Co-supervisor

Declaration by researcher

I, Tahnita Monteiro, hereby declare that this research manuscript, titled, *The appropriateness of the Tower of London^{DX} to measure executive skills in children during neuropsychological assessment: a rapid review,* is my own effort and has never been submitted for examination. I declare that the sources utilised in this dissertation have been referenced and acknowledged. Furthermore, I declare that this mini-dissertation was edited and proofread by a qualified language editor, as prescribed. I lastly declare that this research study was submitted to the Turn-it-in software system and a satisfactory report was received with regard to plagiarism.

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Guidelines for authors

South African Journal of Psychology

Description

This article is presented in the SAGE house style, which complies with the requirements of the *South African Journal of Psychology*. The article will be submitted for possible publication in the *South African Journal of Psychology*. The *South African Journal of Psychology* is owned by SAGE Publications, which publishes a variety of Southern African and African journal titles. The journal publishes contributions from all fields of psychology in English. Empirical research is emphasised; however, the journal accepts theoretical and methodological papers, review articles, short communications, book reviews and letters commenting on articles published in the journal. Articles relevant to Africa, which address psychological issues of social change and development, are prioritised.

Instructions for authors

General

In general, the manuscript must be written in English of a high grammatical standard. It must follow the specific technical guidelines stipulated in the submission guidelines. The American Psychological Association (APA) 6th Edition has been followed in the preparation of the manuscript. The research contained in the manuscript should comply with the accepted standards of ethical practice, presented by the Committee on Publication Ethics (COPE). The journal endeavours to publish accurate, transparent and ethically sound research.

Manuscript style

The *South African Journal of Psychology* follows the SAGE house style guidelines stipulated in the *SAGE UK House Style guidelines*. New submissions should not exceed 5 500 words, including references, tables, figures, etc. The following format is required for research-based manuscripts:

- The introductory/literature review section requires no heading.
- The following headings/subheadings are required:
    - Method (participants; instruments; procedure; ethical considerations; data analysis, which includes the statistical techniques or computerised analytic programmes, if applicable); Results; Discussion; Conclusion; References.
- In the 'Ethical considerations' section, the name of the institution that granted ethical approval for the study must be stipulated.
- The *South African Journal of Psychology* encourages authors to include a declaration of any conflicting interests.

Format. Only electronic files that adhere to the stipulated guidelines are accepted. The format of the manuscript may either be MS Word or LaTex. All manuscripts must be double-spaced throughout and with a minimum of 3 cm for left- and right-hand margins, and 5 cm at the top and bottom of each page. The text should be in 12 points.

Keywords and abstracts. An abstract of no more than 250 words should be included and should aid readers in finding the article online. Up to six alphabetised keywords should be included in the abstract and always highlighted in the body text. Key descriptive phrases should be repeated and focused on in the abstract. Thus, the abstract must be written in such a way that it conveys the necessary information/data that will assist search engines in finding the article and ranking it on the search results page.

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- EPS is the preferred format for graphs and line art as it retains quality when enlarging/zooming in.

- Placement: Figures/charts and tables created in MS Word should be included in the main text rather than at the end of the document.
- Figures and other files created in formats other than MS Word (e.g. Excel, PowerPoint, JPG, TIFF, EPS, and PDF) should be submitted separately.
- Resolution: Rasterised based files (i.e. with a .tiff or .jpeg extension) require a resolution of at least 300 dpi dots per inch). Line art should be supplied at a minimum resolution of 800 dpi.
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- Fonts: The lettering used in the artwork should not vary too much in size and type. (The default font is usually sans serif.)

Reference style. The journal adheres to the APA referencing style. Specific guidelines are provided, and it is the responsibility of the author or authors to produce an accurate reference list. References are listed alphabetically at the end of the article while in-text references are referred to by name and year in parentheses. The references are structured as follows:

- Last name and initials of all authors
- The year in which the reference item was published (in brackets)
- The title of the article
- The name of the publication
- The volume number
- An issue number (if provided)

- The inclusive pages
- Digital object identifier (DOI)

The *Publication Manual of the American Psychological Association*, 6th Ed., can be consulted for accurate formatting of references. The style and punctuation of the references should conform to the APA style. Examples of the style to be used for books and that for journal articles are given below:

- Journal articles

  Brocki, K.C. & Bohlin, G. (2004). Executive functions in children aged 6 to 13: A dimensional and developmental study. *Developmental Neuropsychology*, *26*(2), 571−593. https://doi.org/10.1207/s15326942dn2602

- Books

  Anderson, V., Northam, E., Hendy, J., & Wrennall, J. (2001). Developmental neuropsychology. A clinical approach. Brain damage, behaviour and cognition series. New York, NY: Psychology Press.

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CHAPTER 1

LITERATURE REVIEW

Introduction

In this section, **key concepts** and **constructs** of the research will be defined and discussed in depth. This will provide a foundation for the brief literature review presented in Chapter 2. In view of the aforementioned, Chapter 1:

(1) clarifies key concepts pertinent to this study;

(2) explains neuropsychological assessments and the appropriateness thereof for use in children, with special mention of appropriateness in the South African context;

(3) provides an understanding of executive skills and functioning, with the focus on executive skills in children;

(4) discusses the neuro-anatomy of executive functions;

(5) discusses the neuropsychological assessment of executive skills; and

(6) briefly focuses on the Tower of London as a measure of executive functioning and its development.

Clarification of concepts

This section contains a clarification of key concepts in order to provide the reader with the understanding needed to engage with the research.

Executive function (EF). This can be broadly defined as a compilation of interconnected processes responsible for purposeful, goal-directed behaviour (P. Anderson, 2002; Blair, 2016). It includes various cognitive skills, namely the ability to monitor, evaluate and hold incoming information in the working memory (based on relevance to the task at hand); impulse control and inhibition; self-regulation of emotion and goal-directed behaviour; planning; problem solving; decision making; social insight; flexibly shifting the mind-set

between two or more mental tasks; and shifting the focus of one's mental frame (Blair, 2016; Lundgren, Högman, Näslund, & Parling, 2016). Good executive functions are thus fundamental to intentional, independent, purposeful, self-serving behaviour in a child's school and everyday life (Blair, 2016). Cognitive skills (also called executive skills) that constitute this construct enable individuals to regulate emotion and to control impulses. These skills also play an important role in decision making. Executive skills contribute to academic success in school, problem solving, planning, behavioural and emotional control, and social interaction (P. Anderson, 2002; Blair, 2016). The concept of executive skills is explored in more detail later in this chapter.

Children. For the purpose of this review, children will be defined as individuals between the ages of seven and fifteen years (Louw & Louw, 2014). This age range was identified by Culbertson and Zillmer (2001) who collapsed their standardised samples of normal and ADHD children into four age groups (7–8, 9–10, 11–12 and 13–15 years).

Tower of London. The Tower of London-Drexel Version (TOL^{DX}) is a professionally administered neuropsychological instrument originally developed by Shallice (1982), with the intention of measuring frontal lobe and executive function processes in adults (Culbertson & Zillmer, 2001). It was developed to assess higher-order problem solving or, more specifically, to study deficits in planning, goal-directed behaviour and problem solving commonly observed in patients with frontal lobe lesions (Albert & Steinberg, 2011; Culbertson & Zillmer, 2001; Rainville, Lepage, Gauthier, Kergoat, & Belleville, 2012).

Rapid review. A rapid review is a research methodology that provides comprehensive, strong information about what is known from previous research, what is still unknown, and how information varies across studies (Gough, Thomas, & Oliver, 2012). It therefore provides a foundation for planning and conducting new primary research while keeping abreast of preceding and new research literature (Gough et al., 2012). Rapid review

findings offer a context for interpreting the results of primary research and ensure that new primary research is not undertaken without being informed by preceding research, which means that unsuitable, inappropriate or unethical research is avoided (Gough, Oliver, & Thomas, 2017).

Rapid reviews streamline the methods involved in systematic reviews in order to synthesise evidence in a shorter time frame, typically in fewer than eight weeks, including protocol publication (Ganann, Ciliska, & Thomas, 2010; Schünemann & Moja, 2015). Throughout the process, the aim is to work in a systematic, transparent and reproducible manner while guaranteeing comprehensiveness and reducing bias in the identification and processing of relevant information (Gough et al., 2012; Gough et al., 2017; Mertz, Kahrass, & Strech, 2016). This is done by limiting aspects of the systematic review process, which shortens the time scale. Techniques used to limit aspects of the systematic review include the following: focusing the research question; using broader search strategies; restricting the amount of grey literature used; extracting only key variables; and performing a simple quality/critical appraisal. The researcher selects the strategy and then explicitly reports the likely effect of the methodology (Grant & Booth, 2009).

Neuropsychological assessment. According to Schoenberg and Scott (2011) neuropsychological assessments are evaluations that, provide unique information about a person's cognitive and behavioural functioning that is quantified and medically necessary, and can be essential for (1) diagnosis (e.g. mild cognitive impairment), (2) describing neuropsychological status, (3) treatment or rehabilitation planning/program placement, (4) monitoring effect of treatment(s), (5) the identification of underlying processes for cognition and/or effects of treatments/other agents, and (6) forensic applications (p. 2).

Anderson, Northham, Hendy, and Wrennall (2001) explain that the questions asked by a paediatric neuropsychologist are, more frequently directed towards gaining an

understanding of the child's' neurobehavioral profile for remediation or rehabilitation: Where is the child in relation to his or her age peers, independent of neurological factors? What is the child's developmental trajectory? What can be done to reduce the gap between the child and his/her peers? (p. 348).

The issue of ascertaining normal developmental trajectories in children is thus also pertinent in neuropsychological assessment in children.

Literature review

Appropriateness of neuropsychological assessments in the South African context

The word *appropriateness* is a noun meaning "the quality of being suitable or proper in the circumstances" (Oxford University, 1989). A test must be age appropriate in that it is appealing, motivating, or appropriate for children or adolescents in terms of their cognitive development (P. Anderson, 2002; V. Anderson et al., 2001; Riccio, Wolfe, Romine, Davis, & Sullivan, 2004). Furthermore, certain factors have to be accounted for when interpreting the performance of children in neuropsychological assessments, such as developmental rate of skills, quality of education, and effects of brain injury on subsequent development (P. Anderson, 2002; Foxcroft & Roodt, 2013; Shuttleworth-Edwards, 2014; Shuttleworth-Jordan, 1996). Paying attention to these aspects makes the neuropsychological assessment "appropriate". At present, challenges faced in South Africa include contextual and developmental difficulties, as well as appropriateness disputes.

Researchers such as Alegret et al. (2012) highlight the need for appropriateness in neuropsychological testing by indicating a growing need for standardised assessments of cognition, specifically assessments that are brief, easily administered, and that have normative data adjusted for age, level of education and race. The level of education and race is especially pertinent as there are large discrepancies in the level and quality of education

among South Africa's learners as a result of formerly disadvantaged schools during the Apartheid era (Shuttleworth-Edwards, 2014). Against the background of significant socioeconomic and sociopolitical challenges in post-Apartheid South Africa, difficulties encountered in the application of neuropsychological tests are twofold (Nell, 2000). Firstly, the practice of applying neuropsychological tests suitable for one ethnic group to another ethnic group (Shuttleworth-Edwards, Donnelly, Reid, & Radloff, 2004). The paucity of normative data that adequately characterise our ethnically, linguistically, socioeconomically and educationally diverse population, hampers psychometric testing of cognitive functioning in South African children (Foxcroft & Rood, 2013; Shuttleworth-Edwards, 2014; Shuttleworth-Jordan, 1996). During norm development, cross-cultural researchers therefore have to distinguish between historically "advantaged", mainstream contexts (found in former Model C and private schools) and mainstream educationally "disadvantaged contexts" (schools that are typically run by the relevant Department of Education in rural areas and townships). The need for this distinction was confirmed and emphasised by cross-cultural researchers in the field (Shuttleworth-Edwards, 2014; Skuy, Schute, Fridjihon, & O'Carroll, 2001).

Secondly, the developmental appropriateness of paediatric neuropsychological measuring instruments in South Africa poses a challenge. Many neuropsychological measures currently in use were developed specifically for adult populations. When used for children, they are "dumbed-down" versions and inappropriate (P. Anderson, 2002; Korkman, Kirk, & Kemp, 2007; Riccio et al., 2004). Neuropsychological tests for children are often not based on "an understanding of the ongoing nature of both cerebral and cognitive development throughout childhood" (V. Anderson et al., 2001, p. 55). The relevance of adult-derived tests or scaled-down versions of tests used for children is questionable when they require the normative data essential for differentiating between normal and abnormal performance within

a developmental context (P. Anderson, 2002). In children, cognitive functions develop rapidly making it difficult to devise tasks that are suitable across the developmental spectrum (P. Anderson, 2002). Therefore, the validation of assessment tools that take the developmental nature of the child population into consideration is more difficult compared to that with the adult population (ibid).

In the last decade, a number of assessments have been devised for specific age ranges throughout childhood (P. Anderson, 2002). Similar studies have been conducted in countries such as Spain to provide normative data for a variety of cognitive assessments and instruments (e.g. Peña-Casanova et al., 2009; Rami et al., 2008). However, at the time of writing, the available literature indicates that no such studies have been conducted for the South African population, with the result that normative data are lacking. Greater selectivity in the measures administered to children is thus required to ensure that their relevance has been determined, adequate standardisation has been established, and they have been validated in suitable childhood conditions (P. Anderson, 2002) and contexts (Shuttleworth-Edwards, 2014).

Executive skills domains in children

Executive skills, an umbrella term, forms part of a multidimensional functional system that involves a number of interconnected and interdependent processes, behaviours and cognitive abilities as already mentioned above (P. Anderson, 2002; Injoque-Ricle, Barreyro, Calero, & Burin, 2014; Rainville et al., 2012; Riccio et al., 2004; Stuss & Alexander, 2000). Authors define executive skills differently, and focus on different aspects thereof. For some, executive skills refer to cognitive control processes, including the ability to enable successful planning and formation of strategies, and maintaining and shifting attention in order to facilitate goal-directed behaviour (Albert & Steinberg, 2011; Riccio et al., 2004; Stuss & Benson, 1984). Other authors define executive skills much more broadly as

complex mental processes that orchestrate purposeful, goal-directed activity (Araujo et al., 2017). These higher order processes are important for adaptive functioning because they allow for the modification of action, inhibition of inappropriate or task-irrelevant activity, and guidance of behaviour in accordance with rules, internal goals and intentions (Jurado & Rosselli, 2007; Miller & Cohen, 2001). Lezak, Howieson, Bigler, and Tranel (2012) is in agreement and states that executive skills refer to the capacities that enable a person to initiate, direct, guide, manage and modulate intentional, independent, purposive, self-serving behaviour. Therefore, executive skills do not merely refer to the fact that a person **can** do something, but also **how** he or she does it, in other words, the quality of the action.

To summarise, a number of authors agree that executive skills are made up of at least four interrelated principal domains as described above, namely: (1) attentional control, which involves selective, focussed and sustained attention; (2) cognitive flexibility, which involves working memory, self-monitoring and attentional/set shifting; (3) goal setting, which involves initiation, planning, strategic behaviour, problem solving and inhibitory control (self-regulation); and (4) information processing (P. Anderson, 2002; Blair, 2016; Bull, Espy, & Senn, 2004; Injoque-Ricle et al., 2014; Lezak et al, 2012; Lundgren et al., 2016; Miyake et al., 2000; Stuss & Benson, 1984).

The development of executive skills. In contrast to former beliefs, executive skills emerge in early childhood and continue to develop and mature until the beginning of adulthood (P. Anderson, 2002; Injoque-Ricle et al., 2014). It is well known that the executive functions of attentional flexibility, inhibition and working memory are already differentiated and dissociable in early childhood, and there is evidence that these components are interrelated (Best & Miller, 2010; Hughes, 1998). They are, however, less efficient in younger normal children compared to older normal children as a consequence of brain development – specifically development of the prefrontal regions of the brain (Brocki &

Bohlin, 2004). Processes such as myelination (the production of the myelin sheath that surrounds neuronal axons) enable fast communication in the brain, which enables "higher order cognitive functioning" (Deoni et al., 2011, p. 784) and synaptogenesis (the development of synapses among neurons in the brain (Huttenlocher & Dabholkar, 1997) progress in a hierarchical sequence during childhood (V. Anderson, 2001). Thus, as children grow and mature, executive skills become more distinct (Lee, Bull, & Ho, 2013).

Specific executive skills have their origin in frontal cortical systems, and have different developmental profiles (P. Anderson, 2002). The frontal structures mature progressively over time owing to increased myelination. This process of maturation correlates with the gradual and ongoing acquisition of the more complex cognitive abilities involved in executive skills. As such, the development of executive skills is consistent with the development and maturation of the frontal regions of the brain and greater interconnectivity with other parts of the brain (Culbertson & Zillmer, 2001; Injoque-Ricle et al., 2014). As stated previously, executive skills are already apparent during early childhood, and their maturation follows a multistage trajectory (Culbertson & Zillmer, 2001). Each domain of executive functioning develops at a different pace making it a complex topic to study, and resulting in different developmental profiles (P. Anderson, 2002; Maeder et al., 2016).

Lee et al. (2013) found the process of executive function differentiation to be prolonged and slow between the ages of six and fifteen years. Furthermore, set shifting and inhibition were found to be closely related to processing speed. The results from their study indicated that various executive skills follow different developmental time courses, and proceed at a different pace, which reinforces the view that executive skills assessments or measures should not be used in isolation (Lee et al., 2013).

To give further impetus to developmental trajectories, Culbertson and Zillmer (2001) found age-related differences in performance on all scores of the TOL^{DX} for both normal and

clinical children. This age-related progression of TOL^{DX} scores indicates that children become increasingly proficient in terms of executive skills as a function of age. Therefore, they are able to plan more efficiently, solve problems more proficiently, work faster, and perform in a more rule-conscious manner with increasing age (Culbertson & Zillmer, 2001). Culbertson and Zillmer (2001) further revealed that cognitively intact children, of age 12 years or older, were able to solve more complex problems on the TOL^{DX} with little difficulty. Thus, problem-solving abilities appear to have achieved adult level performance or developmental maturity by the age of 12 years (Culbertson & Zillmer, 2001; Petousis, 2008).

Research by Steinberg (2008) suggests that developmental gains in executive functioning (cognitive control) in late adolescence, and even during the first year of adulthood, contribute to a progressive capacity to make mature decisions, control impulsive behaviour, learn about costs and benefits in decision making, and the ability to plan, resulting in more effective problem solving (Albert & Steinberg, 2011; Injoque-Ricle et al., 2014). The aforementioned is reinforced by the findings of Petousis (2008), which indicate that at the age of 15 years, sustained attention, planning, processing speed, impulse control, inhibition and organisational abilities reach fuller maturational capacity.

Development of inhibitory functions is thought to be in parallel with the development of the prefrontal cortex (Brocki & Bohlin, 2004). Inhibition shows marked development between early childhood and mid childhood (six to twelve years of age), with decreased changes in young adults (Best & Miller, 2010; Brocki & Bohlin, 2004). Working memory and attentional shifting show gradual linear improvements, with little sign of a plateau, throughout development (Best & Miller, 2010; Lee et al., 2013). We can therefore see that the developmental trajectories of the different components of executive skills vary from age to age and that efficiency in executive control becomes increasingly specialised and independent with age (Best & Miller, 2010; Lee et al., 2013).

The importance of executive skills and the impact of executive function deficits.

As previously stated, executive skills play a significant role in children's cognitive ability, behaviour, emotions, and social interaction and, as such, are essential to mental and physical health, as well as success in both school and life (P. Anderson, 2002; Diamond, 2013). In children, executive skills deficits may be associated with poor impulse control, problems with planning and organising, rule breaking, difficulty in creating and implementing strategies, perseverance and reduced working memory, to name but a few (P. Anderson, 2002; Injoque-Ricle et al., 2014). Chevignard et al. (2009) highlighted that executive skills deficits may only become fully apparent when the processes are fully developed or developmental demands increase on the child. This is due to the fact that executive skills in children are in a rapid state of development and are often still immature at the time of insult, injury or trauma in the case of traumatic brain injuries (Chevignard et al., 2009). When these deficits become apparent they may interfere with a child's capacity to develop normally and interact effectively, therefore resulting in a number of ongoing disturbances in their cognitive, behavioural, academic and social abilities (such as impulsivity and poor self-control) (V. Anderson, 2001; Dores et al., 2014). Executive skills deficits therefore may have a negative impact on future mental health and adult functioning (Injoque-Ricle et al., 2014).

As mentioned previously, a key element of executive skills is the establishment of goals, specifically planning abilities, also called prospective memory (Injoque-Ricle et al., 2014). Planning can be conceptualised as the ability to create and organise sequenced steps, which may be cognitive or behavioural, in goal-directed behaviour (Injoque-Ricle et al., 2014; Rainville et al., 2012). Planning is important for the activities that form part of daily life. In children, effective planning is related to better academic achievement (Injoque-Ricle et al., 2014). A number of studies have been conducted in an attempt to study the impairment of planning and other executive skills during childhood. In these studies, the emphasis was on

developmental disorders, such as attention deficit/hyperactivity disorder (ADHD), specific language impairment, and autism (e.g. Marton, 2008; Solanto et al., 2007). However, few studies have investigated the normal development of these functions (Brocki & Bohlin, 2004; Injoque-Ricle et al., 2014).

The effects of socioeconomic disadvantage on the development of executive skills abilities in childhood have been partially mediated and implicated by the experience of stress by these children and the effect on their stress response (Blair, 2016). Blair (2016) emphasised the importance of the physical and psychosocial characteristics of poverty, which cause high levels of stress in children, thus making their stress response less flexible (Blair et al., 2011). We can therefore see that the shaping of executive skills in childhood as described above, may contribute to poverty-related gaps in school achievement, as well as school readiness (Blair & Raver, 2015).

The abovementioned considerations are of particular significance in the South African context as an assessment would have to account for the current crisis in education in South Africa. The reading, writing and computing skills of most South African children fall below grade-appropriate levels while a large portion of the population is functionally innumerate and illiterate (Spaull, 2013). In 2001, the South African National Department of Education issued its *White Paper 6: Special needs education: Building an inclusive education and training system*, which focused on inclusive education and training, and highlighted that the education system had generally failed to provide the services appropriate for the diverse needs of learners in South Africa. It also highlighted the fact that some learners require intensive, specialised support in order to develop their full potential, and that this support can be provided through Inclusive Education. The document emphasised the importance of early identification of disabilities and intervention, which are complicated owing to the serious human resource constraints currently experienced in South Africa.

Neuro-anatomy of executive functions

The neuro-anatomical regions that mediate and support executive skills are located in the anterior regions of the brain (P. Anderson, 2002; Stuss & Alexander, 2000; Stuss & Benson, 1984). Stuss and Benson (1984) demonstrated that executive skills are supported by abundant neural systems (i.e. the limbic system and the anterior cingulate cortex) that are interconnected with the prefrontal cortex and dependent on efferent and afferent connections with all the brain regions (Stuss & Benson, 1984). The prefrontal cortex is made up of three functional domains: (1) the dorsolateral prefrontal cortex; (2) the orbitofrontal (inferior or ventral frontal lobe) cortex; and (3) the medial frontal/anterior cingulate (Schoenberg & Scott, 2011). Therefore, executive skills are complex and employ broader neural networks and related descending systems (subcortical and posterior cortical regions). These skills utilise the connections among the abovementioned brain areas, and are therefore dependent on many regions of the brain (V. Anderson, 2001; Schoenberg & Scott, 2011; Snyder, 2013). These cortical regions thus supply an intentional framework that allows for the formulation and maintenance of goals, plans, and task-relevant information in the working memory, and that can be adaptively used in novel, problem-oriented situations (V. Anderson, 2001; Snyder, 2013). It is for this reason that executive skills deficits are not always associated with prefrontal pathology only (Stuss & Alexander, 2000).

Functional magnetic resonance imaging (FMRI) studies propose that specific activation of two brain regions support performance in TOL^{DX} problems when executive skills are being performed, namely the dorsolateral prefrontal cortex and the rostrolateral prefrontal cortex (Albert & Steinberg, 2011; P. Anderson, 2002). Studies employing the TOL^{DX} have clearly demonstrated the importance of the prefrontal cortex for executive skills such as complex problem solving (Albert & Steinberg, 2011). In up-to-date limited reviews,

results were synthesised to provide a more specific answer to whether using the TOL^{DX} as a measure of executive functioning in children is relevant and effective.

Neuropsychological assessment of executive skills

Since the 20th century there have been numerous advances in technology, which have made it possible to examine brain structures and increased our understanding of brain behaviour relations (Riccio, Sullivan, & Cohen, 2010). Neuropsychology seeks to advance the understanding of the effects of neurodevelopmental and genetic disorders (Berkelhammer, 2008). Individuals sent for neuropsychological assessment are often referred with the primary aim to identify pathology. This often entails a neuropsychological approach that incorporates information related to various behavioural domains believed to reflect functional neurological systems (Luria, 1980; Riccio & Reynolds, 1998). In such cases neuropsychological assessment is intended to be sufficiently comprehensive to address all the functional systems. Alternatively, an idiographic approach can be adopted, which tailors the selection of measures based on the child's presenting problems, with others added based on the child's performance on initial measures (Berkelhammer, 2008; Luria, 1973). This approach may be more cost effective, which is essential in countries such as South Africa where resources are limited (Riccio et al., 2010).

One of the major purposes of neuropsychological assessments is to pursue the impact of brain abnormality, damage and even dysfunction. Furthermore, they are used to ascertain normal developmental trajectories in children. There is a clear need for adequate normative data (D'Amato, Rothlisberg, & Rhodes, 1997). Varying concerns and issues have resulted in the development of a number of standardised measures while others that have been used reliably in adult populations have not yet been demonstrated as reliable in child populations (Batchelor, 1996). Of interest in more recent years has been the reliability and validity for use of neuropsychological measures across cultures (Harris, Wagner, & Cullum, 2007; Smith,

Lane, & Llorente, 2008). The application of the theoretical bases for understanding brain–behaviour relations, such as the Lurian model, across cultures is also being considered for more and more individuals from a variety of cultural and linguistic backgrounds (Kotik-Friedgut, 2006).

Neuropsychological perspectives provide a base for better incorporation of behavioural data, which will lead to a more holistic understanding of children's functioning (Riccio & Reynolds, 1998). Neuropsychological assessment can be used to ascertain initial functioning and to track progress, thus elucidating intervention needs and referral to other specialists (Berkelhammer, 2008). Neuropsychological assessment can furthermore be used to elucidate the link between neuropsychological assessment and intervention. Enhanced understanding of the neurological associations of various skills, together with knowledge of instructional methods, can support hypotheses on the potential instructional methods and materials to be used with a particular child (Reynolds & Mayfield, 2005). In order to inform interventions, the results have to be integrated with information on the type and number of impaired functional systems. Furthermore, integration of the nature and characteristics of the functional systems that remain intact is also important. Identifying deficits in functional systems may require specific compensatory skills or accommodations in settings such as school. Thus, data obtained from neuropsychological assessments are used to develop recommendations on whether the individual would benefit from compensatory strategies, supportive instruction, or a combination of these (Gaddes & Edgell, 1994; Riccio & Reynolds, 1998).

The Tower of London-Drexel Version (TOL^{DX})

The Tower of London (TOL) was initially developed by Shallice (1982) to assess and identify impairments of frontal-lobe functions in adult patients with frontal lobe damage, thus allowing the study of deficits in goal-directed behaviour often seen in frontal-lobe patients

(Albert & Steinberg, 2011; Culbertson & Zillmer, 2001; Rainville et al., 2012; Riccio et al., 2004). The TOL^{DX} is the most recent revision and an improved version of the traditional Tower of London (TOL) (Culbertson & Zillmer, 1998). The TOL^{DX} was developed to improve limitations of earlier versions, to enhance the measure's clinical utility, applicability and standardisation, and to adjust it for use in children (Culbertson & Zillmer, 1998; Culbertson & Zillmer, 2001; Riccio et al., 2004). Tower tasks are presumed to tap executive functions and problem-solving abilities (Rainville et al., 2012; Riccio et al., 2004). In this new version, the TOL^{DX}, planning ability components of executive problem solving are the central constructs assessed (ibid). Modifications made in the TOL^{DX} include: (1) the addition of more complex items through the introduction of six- and seven-move test configurations, thus increasing the sensitivity of the measure to executive functioning across age levels; (2) the stipulation of multiple standard scores; (3) the introduction of an interval-scaled scoring system thus increasing the sensitivity of the measure to executive functioning across age levels; (4) a comprehensive manual with instructions for administration, scoring and interpretation (including normative data for nonclinical children, adults and a sample of children with attention, impulse, and activity dyscontrol); (5) the elimination of repeated trials for failed items, which ensures that task novelty is maintained by permitting only one attempt per item and thus also reduce practice effects; (6) an empirical selection of test problem configurations in order to assess the range of executive planning abilities (Culbertson & Zillmer, 1998; Culbertson & Zillmer, 2001; Riccio et al., 2004).

The results of a study by Riccio et al. (2004) suggest that the TOL^{DX} measures aspects of ability not tapped by other measures, and therefore may possibly provide information on individual functioning. However, the results of such measures should not be used to interpret the absence or presence of a disorder (Riccio et al., 2004). A clear understanding of cognitive development is crucial when working with children and adolescents as this permits early

identification of possible developmental deviations, improves diagnostic competencies and aids in the development of age-appropriate treatment plans (P. Anderson, 2002). The developmental expectations of executive skills have to be understood because dysfunctions may not be considered deviant in the case of children when viewed in a developmental context (P. Anderson, 2002). Once population-specific norms have been established (e.g. children from advantaged schools versus children from disadvantaged schools) we shall begin to observe the "normal developmental trajectory" for children coming from specific contexts.

The TOL^{DX} administration procedure. The TOL^{DX} involves two tower-structure boards, two sets of beads, a technical manual and record forms for adults and children (Culbertson & Zillmer, 2001). The measure consists of ten problems of increasing difficulty. The examiner uses a tower and a set of beads to display a desired goal, and the examinee is required to rearrange a second set of beads mounted on three vertical pegs to match the target configuration presented by the examiner's tower structure (Culbertson & Zillmer, 2001; Injoque-Ricle et al., 2014; Riccio et al., 2004). This must be achieved in a minimum number of moves while adhering to specific rules, and completed within a time limit of 160 seconds (Albert & Steinberg, 2011; Levin et al, 1994; Riccio et al., 2004). In order to plan a solution to a difficult trial, the examinee must mentally represent a path from start state to goal state, which requires multiple intermediate steps organised as sub-goal operations (Albert & Steinberg, 2011).

Scoring the TOL^{DX}. Eight scoring variables are used to represent different aspects of executive-planning and problem-solving abilities (Culbertson & Zillmer, 2001). As mentioned previously, trials vary in complexity based on the minimum number of moves necessary to accomplish the solution (Albert & Steinberg, 2011). It is for the aforementioned reason that difficult trials assess complex, integrative problem solving by requiring goal

directedness, strategic planning, inhibition of certain responses, and recall-guided action (Albert & Steinberg, 2011; Berg & Byrd, 2002). Standard scores are obtained for the total number of moves, total initiation time, total problem-solving time, total execution time, number of correct solutions, total time violations, and total rule violations (type 1 and type 2) (Culbertson & Zillmer, 2001; Riccio et al., 2004).

The TOL^{DX} as a suitable measure of executive skills. This measuring instrument is considered a valid measure of executive skills in both adults and children abroad (outside of Africa), and is one of many tasks used in the assessment of executive skills and functions. It is also broadly used in clinical settings (Rainville et al., 2012; Riccio et al., 2004). As discussed previously, one of the key elements in executive skills is the establishment of goals, specifically planning abilities (Injoque-Ricle et al., 2014). Prospective memory planning can be conceptualised as the ability to create and organise sequenced steps, which may be cognitive or behavioural, in goal-directed behaviour (Injoque-Ricle et al., 2014; Rainville et al., 2012). Planning is important for the activities of daily living. In children, effective planning is related to higher academic achievement. Although a number of studies have been conducted in an attempt to study the impairment of planning and other executive skills during childhood with an emphasis on developmental disorders, few studies have investigated the normal development of these functions (Injoque-Ricle et al., 2014).

Planning ability is commonly measured by the TOL^{DX}, and impairments have been illustrated for various clinical populations such as patients with frontal lobe lesions, Parkinson's disease, and Alzheimer's dementia (Köstering, Nitschke, Schumacher, Weiller, & Kaller, 2015; Rainville et al., 2012). The TOL^{DX} scores of children with ADHD were subjected to one-way analysis of variance (ANOVA) and post-hoc comparisons; group differences in scores were found with the ADHD group performing significantly worse (Culbertson & Zillmer, 2001). Thus the TOL^{DX} exhibits good clinical and criterion validity

and represents an accurate assessment measure of executive skills by revealing executive dysfunction in clinical populations (Rainville et al., 2012; Sullivan, Riccio, & Castillo, 2009). Evidence of the TOL^{DX}'s clinical validity can be found in the existing literature (see Sullivan et al., 2009). Injoque-Ricle et al. (2014) showed that analysis of the planning time and analysis of the total score show evidence in favour of the construct validity of the TOL^{DX}, and both measures have been shown to be valid planning measures in adults (Injoque-Ricle et al., 2014).

TOL^{DX} norms. The TOL^{DX} norms presented in the manual represent children and adults ranging from seven to eighty years of age. Seven sites in the United States and Canada were selected for recruiting the normative sample. The sites included public schools, which allowed children to be included in the sample. The children selected for participation were from lower to upper middle-class families and displayed a history of at least average academic achievement with no behavioural or study problems (Culbertson & Zillmer, 2001). At present, there are no South African-based normative data for the TOL^{DX}.

Current gaps in TOL^{DX} research. In most studies done to date the TOL^{DX} was included in a broad battery of tests (Rainville et al., 2012). Additional research is needed to identify the potential appropriateness of TOL^{DX} performance as part of a selective neuropsychological assessment battery (Riccio et al., 2004). This can assist in providing information about normal development of executive skills or planning ability in children. Such information is of importance for educators and psychologists alike since it will enable early identification of impairments in executive functions (Injoque-Ricle et al., 2014), as well as the extent to which the results of the TOL^{DX} could be used to differentiate between children with clinical diagnoses and children with no clinical diagnosis (Riccio et al., 2004). Appropriate measures of executive skills in the neuropsychological assessment of both non-clinical and clinical populations are therefore crucial (Köstering et al., 2015) because it will

impact on the intervention and treatment plans used (P. Anderson, 2002). This is of particular interest in countries such as South Africa where the population is diverse and the quality of education differs greatly, both of which have an impact on children's performance in neuropsychological assessments.

The suitability of the TOL^{DX} in the South African context. The TOL^{DX} has a number of advantages, including its non-verbal nature (i.e. complex verbal ability is not required), the use of simple instructions that are easy to understand, and the fact that because it is a new type of task for most individuals, there are no sub-routines for solving problems (Rainville et al., 2012). Therefore, the TOL^{DX} is a potentially good tool for neuropsychological assessment in countries such as South Africa where language barriers present a huge problem with regard to assessment measures. To our knowledge, research on the TOL^{DX} is limited and has not yet been utilised to identify executive skills deficits and other disorders in child populations anywhere in the world, including South Africa (Rainville et al., 2012; Riccio et al., 2004). In future, the maturation of executive skills can be mapped through developmental and normative studies (P. Anderson, 2002). A conceptual model for executive skills will offer a framework for creating assessment protocols, interpreting test performance and adaptive functioning, and formulating treatment and management strategies (P. Anderson, 2002). In countries such as South African, populations are diverse and the quality of schooling varies across the country. Therefore, we cannot generalise norms from one educational context to another. It is for this reason that we need normative data in South Africa and demographically similar countries.

Summary and conclusion

This literature review endeavoured to elucidate the central concepts and challenges with regard to appropriate and valid neuropsychological measurement of executive functioning in childhood globally, and more specifically in South Africa. The importance of executive skills for ongoing cognitive development, academic performance and well-being in children was highlighted in the literature. Furthermore, the need for developmentally and contextually appropriate, accurate and reliable neuropsychological measuring instruments for executive skills in children was reiterated. Executive skills measurement for diagnosis and intervention planning is of particular importance and use for all psychologists who engage in neuropsychological practice, as well as for teachers and parents who have to make adjustments for the needs of these children during learner support.

At the time of writing, no reviews could be found in which results were synthesised to provide a more specific answer as to whether it is appropriate to use the TOL^{DX} as a measure of executive functioning in children before resources are spent on developing norms for South Africa. Hence the research question underlying this study: What scientific evidence exists regarding the appropriateness of the use of the TOL^{DX}, with specific reference to the neuropsychological assessment of executive skills in children?

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CHAPTER 2

ARTICLE

The appropriateness of the Tower of London^{DX} to measure executive skills in children during neuropsychological assessment: a rapid review

Manuscript for examination

Manuscript title, authors and contact details

The appropriateness of the Tower of London^{DX} to measure executive skills in children during neuropsychological assessment: a rapid review

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Abstract

This study aimed to explore the appropriateness of the TOL^{DX} as a measure of executive functioning in children. In order to answer the research question, a rapid review was employed to explore what scientific evidence exists regarding the appropriateness of the use of the TOL^{DX}, with specific reference to the neuropsychological assessment of executive skills in children. Subsequently four themes were identified, namely: (1) evidence that the TOL^{DX} has diagnostic/clinical utility, (2) evidence that the TOL^{DX} is a valid and reliable measure in children, (3) evidence that the TOL^{DX} is able to differentiate between different age levels, and (4) limitations of the TOL^{DX}. Following this it was recommended that further research and future focus, in terms of research, on neuropsychological assessments in countries such as South Africa be undertaken.

Keywords: children, executive functions, executive skills, neuropsychological assessment, rapid review, Tower of London^{DX} (TOL^{DX})

Word count: 8037

The appropriateness of the Tower of London^{DX} to measure executive skills in children during neuropsychological assessment: a rapid review

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Executive skills is a complex construct and have been defined in diverse ways (e.g. P. Anderson, 2002; Lezak, 1982; Lundgren, Högman, Näslund, & Parling, 2016). Nevertheless, there is a general shared consensus that executive skills are higher-level cognitive processes, which direct, regulate and control lower-level processes to guide behaviour towards a goal, particularly in non-routine activities (Gilbert & Burgess, 2008; Snyder, 2013). These higher-level processes encompass the skills and abilities necessary to formulate purposeful, complex, goal-directed activity; plan strategies while holding the goal in active memory; carry out plans effectively; and monitor and self-correct spontaneously and reliably (V. Anderson, 2001; Dores et al., 2014; Howieson & Lezak, 2012; Lezak, 1982, 1984). A number of authors agree that the term "executive skills" or "executive functions" is best understood as an umbrella concept that encompasses a wide range of interconnected and interrelated, but distinct, mental capacities, cognitive processes and behavioural competencies (V. Anderson, 2001; Chan, Shum, Toulopoulou, & Chen, 2008; Chevignard et al., 2009; Lezak, 1982; Stuss & Benson, 1984). These mental capacities are a collection of related but distinct abilities that include processes such as verbal reasoning; self-regulation of affect; motivation and arousal; self-monitoring during problem solving and self-evaluation; planning; sequencing; abstract thinking; concept formation; the ability to focus and sustain attention; initiation of behaviour; generation and implementation of strategies; nonverbal working memory; monitoring of verbal working memory, including the inhibition of responses and irrelevant information; resistance to interference; utilisation of feedback;

multitasking; mental flexibility; and the ability to deal with novelty (V. Anderson, 2001; Chan et al., 2008; Chevignard et al., 2009; Dores et al., 2014; Lundgren et al., 2016; Stuss & Benson, 1984). Executive skills enable individuals to understand long-term consequences of actions and behaviours, and to recognise alternative approaches to solving novel, complex tasks (Chevignard et al., 2009). Executive skills are at the heart of and are essential for independent, appropriate, socially responsible, and self-serving conduct, and are thus important in constructive and creative activities (V. Anderson, 2001; Lezak, 1982).

The effects of executive skills impairment

Impairments in executive skills result in the individual's leading a compromised life characterised by a number of emotional, psychological, and behavioural problems or disorders (Lezak, 1982; Snyder, 2013). Executive skills deficits or impairments can therefore be a risk factor for future mental health and adult functioning, and have been associated with a number of disorders, including schizophrenia, attention deficit/hyperactivity disorder, and major depressive disorder (P. Anderson, 2002; V. Anderson, 2001; Snyder, 2013) .

Executive skills impairments or deficits can be identified in a child's test performance through the presence of poor planning abilities; poor organisational skills; poor initiation; complications with the generation and implementation of strategies for problem solving; erratic, careless responses; a lack of perseverance; impulsivity; the inability to correct errors; poor self-control; and inflexible or concrete thought processes (V. Anderson, 2001; Howieson & Lezak, 2012; Stuss & Benson, 1984).

Neuropsychological assessments and executive skills in children

The information obtained from neuropsychological evaluations and assessments can be used for treatment planning, vocational training, determining competency, and counselling for the patient and his or her family (Howieson & Lezak, 2012). Commonly used standard executive function neuropsychological assessments include the following: Trail Making Test;

Wisconsin Card Sorting Test (WCST); Rey-Ostereith Complex Figure Copy (RCF); Tower of London (TOL); and Complex Figure of Rey (V. Anderson, 2001; Chevignard et al., 2009). There is however disagreement as to which of these assessment measures is a more valid indicator of executive function (V. Anderson, 2001; Dores et al., 2014). A review of studies designed to assess executive skills, showed that individual researchers vary in their opinion as to which assessment measure provides the best measures of executive function (V. Anderson, 2001).

When taking into account the nature and diversity of executive skills, there are a number of difficulties related to terminology, assessment, and rehabilitation (Dores et al., 2014). Accurate and reliable identification of executive function deficits continues to be limited due to a lack of developmentally appropriate assessment tools (V. Anderson, 2001). Todd (1996) highlighted the important consequences of deficits' being inaccurately interpreted by clinicians as injury-related consequences, rather than developmentally inappropriate levels of skills.

Most of the aforementioned standard measures of executive function have been developed and validated for use in adult populations (P. Anderson, 2002; Riccio, Wolfe, Romine, Davis, & Sullivan, 2004). Their use in children is based on the assumption that they will detect similarly localised dysfunction in both adults and children (V. Anderson, 2001). Adult-derived tests may be of little interest or relevance to young children, which is problematic because the establishment of expected normal levels of executive function in children and adolescents is important (Todd, 1996). Certain factors need to be accounted for when interpreting the performance of children on neuropsychological tests, including the developmental rate of skills, quality of education, and effects of brain injury on subsequent development (P. Anderson, 2002). Assessment of executive functions in children is challenging as cognitive functions develop rapidly making it difficult to devise tasks that are

suitable across the developmental spectrum (P. Anderson, 2002). In order to establish valid measures that overcome the problems described above, it is essential to evaluate their capacity to measure the primary skills included in definitions of the concept (discussed above) (Duncan, 1986; Luria, 1973; Welsh & Pennington, 1988). This makes the validation of assessment tools in a developmental framework more difficult than it would be to achieve in the adult population (ibid). Research by Alegret et al. (2012) indicates a growing need for standardised and valid assessment measures of executive skills, and specifically for using assessments that are brief, easily administered, and have normative data adjusted for age and level of education, as well as quality of schooling, while being based and grounded in the understanding of cerebral and cognitive development throughout childhood (V. Anderson, 2001; Shuttleworth-Edwards, Donnelly, Reid, & Radloff, 2004).

The Tower of London

The Tower of London-Drexel University (TOL^{DX}) is the most recently developed version and revision of the traditional Tower of London (TOL) (Riccio et al., 2004). The TOL^{DX} is a neuropsychological assessment instrument designed to assess higher-order problem solving in both adults and children, and was traditionally viewed as a planning or problem-solving task (Culbertson & Zillmer, 2001; Rainville, Lepage, Gautheir, Kergoat, & Belleville, 2012). It was developed and modified in order to improve on the limitations of the previous versions and to enhance its clinical utility, applicability, and standardisation for child and adult populations (Culbertson & Zillmer, 2001).

The TOL^{DX} is now a widely used instrument in the assessment of executive skills, is considered a valid measure (Rainville et al., 2012), and is often used in clinical practice (Rainville et al., 2012; Riccio et al., 2004). The TOL^{DX} has been used as a measure of planning ability, employed to identify and specify executive deficits in clinical and normal

populations, and is predictive of impairment in everyday functioning (Rainville et al., 2012; Sullivan, Riccio & Castillo, 2009).

Performance of the TOL^{DX} requires the coordination of multiple aspects of executive skills; these are distinct but interactive cognitive abilities often collectively referred to as planning (Rainville et al., 2012; Snyder, 2013). The TOL^{DX} induces varying cognitive demands, including formulating goals, selecting moves, inhibiting impulses, sequencing and maintaining moves in working memory, and monitoring progress towards a goal while abiding by the rules (Albert & Steinberg, 2011; Snyder, 2013). The TOL^{DX} has a number of advantages, including its non-verbal nature that does not call for complex verbal abilities, and the maintenance of task novelty, which is important in invoking executive skills (Köstering, Nitschke, Schumacher, Weiller, & Kaller, 2015; Rainville et al., 2012)

Over the last decade the number of publications on executive skills and their assessment has increased, indicating the complexity and significance of these particular areas of study (Dores et al., 2014). In most studies done to date, the TOL^{DX} was included in a broad battery of tests (Rainville et al., 2012). Additional research is needed to identify the potential usefulness of TOL^{DX} performance as part of a comprehensive neuropsychological assessment battery (Riccio et al., 2004). This can assist in providing information about the normal development of planning ability in children, and about the extent to which the results of the TOL^{DX} could be used to differentiate children with clinical diagnoses from children without clinical diagnosis (Injoque-Ricle, Barreyro, Calero, & Burin, 2014; Riccio et al., 2004). This is of importance for educational and psychological professionals in the early identification of impairments in executive skills, and is of particular interest in countries such as South Africa where the population is diverse and the quality of education differs greatly, both of which impact children's performance on neuropsychological assessments. To date no reviews, apart from the developers themselves, have been published on the appropriateness of the use of the

TOL^{DX} to measure executive skills in children during neuropsychological assessment. Given the above, the research question asked in this current rapid review was: What scientific evidence exists regarding the appropriateness of the use of the TOL^{DX}, with specific reference to the neuropsychological assessment of executive skills in children?

In addressing this question the researcher hoped to determine whether the TOL^{DX} is recommended for use in children in South Africa. The current study was limited to children between the ages of seven and fifteen years. The exclusive focus on children in the study was motivated by findings that most neuropsychological assessments are developed and standardised for adult populations, as discussed previously (P. Anderson, 2002; Korkman, Kirk & Kemp, 2007; Riccio et al., 2004).

Aims and objectives

The aim of this study was to explore the appropriateness of the TOL^{DX} as a measure of executive functioning in children. Consequently a rapid review was conducted, and the research findings of existing scientific literature on the use of the TOL^{DX} as a neuropsychological assessment of executive skills in children were synthesised.

Methodology

Research design

A rapid review methodology was employed, which streamlined the methods involved in systematic reviews in order to synthesise evidence in a shorter timeframe (Ganann, Siliska, & Thomas, 2010; Schünemann & Moja, 2015). The study had a narrow, focused and specific question; extracted only key variables; was primarily, but nor exclusively, conducted by three reviewers; had a limited timeframe, and referred to studies published in English only (Grant & Booth, 2009). Because there were no articles reviewing the use of the TOL^{DX} on children in South Africa, a global review of the TOL^{DX} in children was undertaken instead.

Data generation

The research process of this rapid review was guided by the steps set out by Gough, Oliver and Thomas (2017) and by Godfrey and Harrison (2015). This ensured that the research adhered to the requirements set out for systematic reviews.

Phase 1 involved the formulation of a clear and well-defined research question (Gough et al., 2017) based on identifying gaps in existing research. A scope search was conducted in consultation with a librarian at North-West University (NWU). This search yielded 91 studies (see Figure 1), which indicated that the study was feasible and that there were relevant search results to the aim of the study.

In Phase 2 a comprehensive search was conducted, using the final keywords, through the EBSCO Discovery Service (EDS), available on the NWU database search portal. EDS allows for the search of 73 international and national databases through one search engine. Keywords were identified by searching psychology journals and textbooks on the topic and through the National Library of Medicine's (2017)-Medical Subject Headings (MESH) (https:/www.nlm.nih.gov/mesh/MBrower.html) (see *Table 1* for the final keywords).

The following inclusion criteria were used to include studies in the review: full text, peer-reviewed empirical journal articles and PhD theses in English; published since 1998 (development of the TOL^{DX}); studies following either quantitative, qualitative, or mixed-method approaches; study participants had to be children between the ages of 7 and 15 years. The following criteria were used to exclude studies from this review: studies published in conference proceedings; non-research reports; letters and commentaries; master's dissertations and mini-dissertations; review studies; and studies utilising non-probability sampling.

Table 1

Final Keywords

Field	**Keywords**
All text	*"Executive function*" OR "executive skill*" OR "executive process*"* AND
Abstract	*"Tower of London DX" OR "TOLDX" OR "TOL" OR "Tower task*" OR "Tower test*"* AND
All text	*"Neuropsychological assessment*" OR "neuropsychological test*" OR "psychometric assessment*" OR "psychometric test*"* AND
All text	*"Child*" OR "children*" OR "adolescent*" OR "teenager*" OR "youth*" OR "juvenile*"*

One researcher independently reviewed the titles and abstracts of articles for relevance and then assessed the selected full text studies to determine their relevance according to the inclusion and exclusion (eligibility) criteria (Ganann et al., 2010). The study leader was invited to settle or resolve any uncertainty and a second study leader settled any further disagreement. Through full text review of relevance, 19 articles were identified. All retrieved documents were collected into a reference manager to enable preceding de-duplication screening. See *Figure 1* for the search strategy results.

Phase 3 consisted of the critical appraisal of relevance and quality of selected studies. The eight criteria used in this study were: (1) was the study relevant to the research question and aims of our study?; (2) was the problem statement and aim of the study made clear?; (3) was appropriate methodology used?; (4) was a random sample or appropriately motivated non-random sample used?; (5) were the results of the study clearly indicated?; (6) were the

results of the study clearly and appropriately interpreted?; (7) were clear and appropriate conclusions and recommendations provided?; and (8) compliance with version TOL^{DX}. The critical appraisal of selected studies was conducted independently by the researcher and two study leaders. Findings were later compared and discrepancies discussed among researchers, which ensured that eligibility criteria were met without bias. Studies were only included if they complied with criterion eight, and at least with four other criteria by both the reviewer and the two study leaders. See *Appendix A* for the results of the critical appraisal.

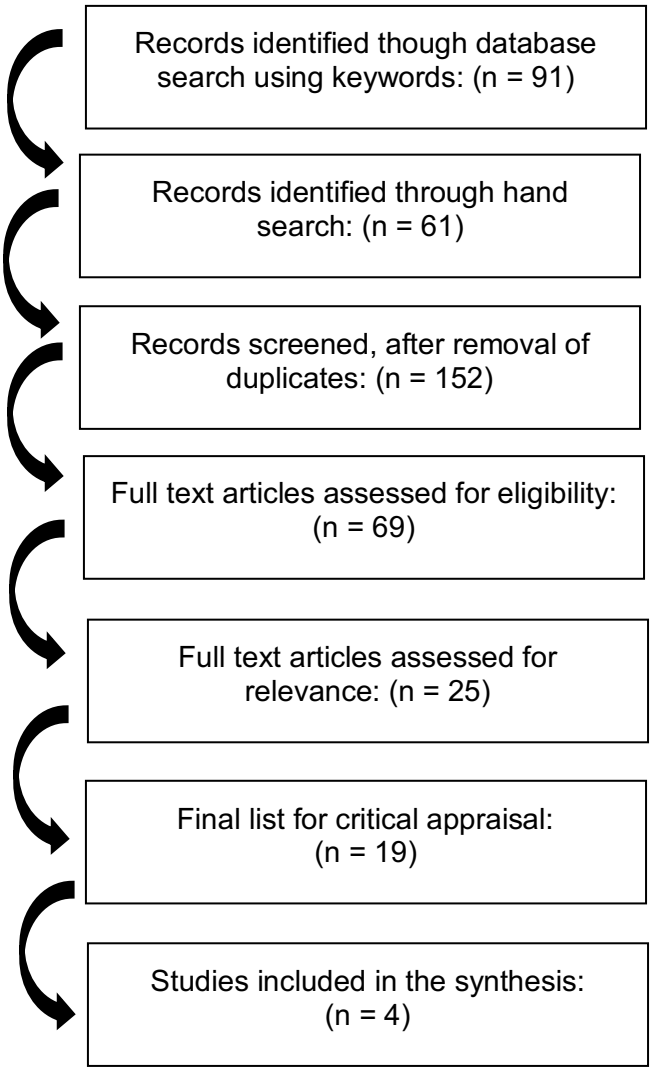

Figure 1. Search strategy results

Data analysis

Phase 4 entailed data extraction and summary of relevant aspects of the final selected studies to answer the review question (Godfrey & Harrison, 2015). For the purpose of this study, a combination of the JBI and EPPI data extraction templates (see *Table 2*) were utilised. Data extraction was completed by the researcher, reviewed by the study leaders, and then discrepancies were resolved (Haby et al., 2016; Handu et al., 2016).

Phase 5 entailed the integration and synthesis of information obtained in the previous steps to form themes and subthemes. Thematic analysis was utilised to identify themes across individual articles (Fereday & Muir-Cochrane, 2006). Selected articles were analysed in accordance with the three-step approach set out by Godfrey and Harrison (2015), namely (1) identifying findings; (2) grouping findings into categories; and (3) grouping categories into synthesised findings. Once the findings of the studies had been identified, all similar findings were combined into categories. Differences and similarities between categories and findings were identified along with themes and subthemes (Palm, 2013). Although only the researcher completed this step, findings were checked and discussed with the study leaders.

Table 2

Data Extraction

#	Title of article	Authors & publication date	Methodology	Participants	Country	Aims and objectives	Data analysis	Ethics	Main findings
1	The Tower of London ^{DX}: A standardized approach to assessing executive functioning in children	Culbertson, W.C. & Zillmer, E.A. 1998	Quantitative Cross-sectional comparative correlational design	2 cross-sectional samples (96% Caucasian) (1) Normal sample = 56 participants divided into 2 groups. Equal representation of males & females • Group 1 (n = 28): children 7 - 9 years • Group 2 (n = 28): children 10 -12 years (2) ADHD sample = 99 participants divided into 2 groups. 95.5% males. • Group 1 (n = 56): children 7- 9 years • Group 2 (n = 43): children 10 - 12 years	United States of America	To standardise the instruction and scoring, determine the clinical utility of TOL^{DX}	One-way analysis of variance (ANOVA)	(a) Informed consent obtained (b) Participants tested by licensed psychologist in a quiet room	• Age-related difference noted for normal and ADHD children (increasing executive planning and problem-solving efficiency with increasing age) • Age-related differences were clearly observed for ADHD children • ADHD children showed significant decrease in Rule Violations with age • Young AHDH children (7–9 years) exhibited significantly greater number of rule violations compared to normal children of same age (differences attenuated with age) • Both age groups of normal children exhibited superior performance across scoring variables • Time variables showed age-related changes with younger (7–9 years) normal children exhibiting slower solution and total problem-solving times than older (10–12 years) children • Efficiency of planning is greater for older children (10–12 years), as evidenced in their lower move and violation scores. Thus older children have greater accuracy and speed of performance • Test-retest reliability for ADHD children was found to demonstrate suitable stability over a two-week period • The criterion validity was supported by the significant difference in performance of ADHD children compared to normal children across scoring variables • ADHD children demonstrated significantly poorer and inefficient executive planning and problem solving • TOL^{DX} demonstrated appropriate classification rates to support its clinical utilisation • The measure is sensitive and highly specific to ADHD • Preliminary reliability and validity results are supportive of the TOL^{DX} as a measure of executive planning and problem solving
2	Clinical utility of the Tower of London-Drexel University, 2nd edition (TOL^{DX}) after adolescent traumatic brain injury	Donders, J. & Larsen, T. 2012	Quantitative Cross-sectional comparative correlation design	2 groups with 43 participants each • Aged between 11 & 15 years • 29 males & 14 females • 79% Caucasian	United States of America	Investigate clinical utility of the TOL^{DX} in evaluation of sequelae of paediatric traumatic brain injury (TBI)	Standard scores for TOL^{DX} variables were used in the statistical analyses:	(a) Institutional review board approval (b) All data in compliance	• Clinical participants had statistically significantly lower TOL^{DX} scores than demographically matched healthy controls associated with acceptable classification accuracy • This was the first study to demonstrate that the TOL^{DX} is sensitive to severity of TBI and can distinguish adolescents with such a diagnosis from neurologically healthy individuals with reasonable accuracy

				(1) Clinical group-participants with a traumatic brain injury (TBI) (2) Control group-matched on age, gender and ethnicity			(1) Multivariate analysis of variance (MANOVA) (2) Logistical regression (3) Hierarchical linear regression (4) Pearson product–moment correlations	with regulations of review board	• The variables with the clearest criterion validity were total initiation time and total execution time • Adolescents with TBI had lower standard scores on both total initiation time and total execution time than control participants • Findings suggested that adolescents with TBI took considerably longer than controls to complete the TOL^{DX} items • The two groups did not differ significantly on the variable total correct score suggesting that adolescents with TBI typically arrived at the overall correct solution, but did so in a less strategic and less efficient manner than neurologically healthy individuals • TOL^{DX} has acceptable clinical utility in the context of a more comprehensive neuropsychological evaluation of adolescents with TBI • TOL^{DX} appears to offer reliable and valid diagnostic information that is non-redundant with that of other well-validated tests of executive functioning
3	Visuo-spatial processing and executive functions in children with specific language impairment	Marton, K. 2008	Quantitative Ex post-facto (comparative) design	(1) 25 children with specific language impairment (SLI) (2) 25 typical developing peers (TLD) • Aged 8–11 years • 8 females & 17 males in each group	Hungary	(a) To examine executive functions, visuo-spatial processing and working memory in children with specific language impairment (SLI) and in their typically developing peers (TLD)	One-way analysis of variance (ANOVA)	(a) To decrease experimenter bias the research assistant that performed scoring and data analysis did not know the participants and their language status	• Children with SLI performed with lower accuracy than their age matched peers • There was no group difference in the scores for total move, total time, and execution time • There was a group effect in initiation time (children with SLI showed shorter initiation time than TLD peers) • Children with SLI showed more impulsive behaviours (shorter initiation time) • The total scores and rule violation score (Children with SLI frequently violated the basic rules) indicated that children with SLI had more difficulty with controlled attention and simultaneous goal maintenance/processing than TLD peers • Children with SLI were less able to keep task-relevant information active in distracting contexts than their peers • Children with SLI performed with more errors in visu-spatial planning than their peers • Children with SLI made a similar number of moves within the given timeframe; however, more of their moves were incorrect than TLD peers • Children with SLI showed a weakness in attention control and inhibition • The results indicated that children with SLI have difficulties in generating concepts and switching from one idea to another • Findings suggest that a weakness in executive functions and attention control has a great impact on both verbal and visuo-spatial processing and working memory in children with SLI
4	Neurocognitive functioning in AD/HD, predominantly inattentive and combined subtypes	Solanto, M.V., Gilbert, S.N., Raj, A., Zhu, J., Pope-Boyd, S., Stepak,	Quantitative Cross-sectional comparative	• Diverse sample in respect of socio-economic characteristics (lower, middle, and upper income levels)	United States of America	To test diagnosed ADHD subtypes and typical children on measures to reveal	(a) Separate MANOVAs/ MANCOVAs were performed for each	(a) Institutional Review Board at Mount Sinai approval	• The CB group had significantly more total moves and total rule violations than the other groups • Both AD/HD groups had longer execution times than TC, with significant group effect • Group effect for rule violations (CB group worse than PI)

		B., Vail, L. & Newcorn, J.H. 2007	correlational design	• Aged 7–12 years (1) 60 children with a diagnosis of ADHD. • 34 combined subtype (CB) • 26 predominantly inattentive subtype (PI) (2) 20 typically developing children (TC) Both groups were medication-naive (psychotropic drugs)		hypothesised differences between the subtypes in specific neurocognitive systems and processes	test yielding multiple scores (b) Post-hoc pair-wise comparisons of significant results were conducted using the method of least significant difference (LSD) (c) Categorical variables were analysed by chi-square		• On the neurocognitive battery, before controlling for IQ, children with CB performed more poorly than the TC and PI groups in respect of: observational measures of motor impulsivity while performing cognitive tasks; visual-spatial working memory and planning (total moves); and memory • Children with PI were indistinguishable from typical comparisons, with the exception of execution time, where they were as slow and as variable as children with CB • After controlling for group differences in IQ, remaining subtype differences were primarily on the observational measures of impulsive behaviour, with the CB group showing greater impulsivity than both the PI and TC groups • The PI group had slower processing speed than the CB and TC groups • After controlling for IQ, there were no group differences in the primary indices of working memory and planning • Results failed to replicate previously reported differences between CB and TC groups on some measures of executive function • Different results across studies may be attributable to varying co-morbidities within the AD/HD samples

Scientific rigour

The same rigour used in systematic reviews according to the scientific community of the Cochrane Collaboration, Campbell Collaboration, or institutions such as the Institute of Medicine or the National Institute for Health and Care Excellence (NICE), was applied in this rapid review (Mertz, Kahrass & Strech, 2016).

Validity and reliability were upheld through the following ways: (1) All full texts reviewed for relevance were discussed with the study leader ensuring eligibility criteria were applied in an unbiased way. (2) The critical appraisal was conducted by the researcher and two study leaders, independently and without discussion. This ensured that eligibility criteria were applied in an unbiased way and that each study included had sound a scientific base, had an appropriate research design and was relevant to the research question. (3) AMSTAR, an instrument for evaluating systematic reviews, was utilised (Shea et al., 2009). It is reliable, valid, and easy to use. Furthermore, it enables one to carry out rapid and reproducible assessments of systematic reviews (ibid).

Currently, there is no agreement on which instrument to use when measuring the quality of reviews. AMSTAR, a development of existing instruments, provides a possible solution and thus was utilised to assess the quality of this study (ibid).

Ethical considerations

This study was submitted to and approved by the scientific committee of the research entity Compress (Community Psychosocial Research) at North-West University. Ethical risk factors or risk of harm were low to none as rapid reviews do not make use of participants directly involved in the research. The ethical guidelines set out by the Health Professions Council of South Africa (HPCSA) (2008) and Wager and Wiffen (2011) were followed. As such, the researcher attempted to maintain a research process that was transparent, accurate, and void of redundant publications or plagiarism. Other ethical aspects that were considered,

were: professional competence (researchers registered at HPCSA and continued professional development and training in research methodology and ethics); upholding scientific integrity (using strategies for establishing rigour and trustworthiness); and no conflict of interest.

Results

The final group of four selected articles (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Marton, 2008; Solanto et al., 2007), had been published between 1998 and 2012. All four articles followed quantitative research design, typically involving statistical comparison between groups and variables. Sample sizes ranged from 50 to 155 participants ranging in age from 7 to 15 years. All studies utilised the TOL^{DX}; two (Culbertson & Zillmer, 1998; Solanto et al., 2007) focused on attention deficit/hyperactivity disorder (ADHD), one (Donders & Larsen, 2012) focused on traumatic brain injury (TBI), and one (Marton, 2008) focused on specific language impairment (SLI).

Four main themes were identified from the analysis, namely: (1) evidence that the TOL^{DX} has diagnostic/clinical utility; (2) evidence that the TOL^{DX} is a valid and reliable measure in children; (3) evidence that the TOL^{DX} is able to differentiate among age levels; and (4) limitations of the TOL^{DX}.

Evidence that the TOL^{DX} has diagnostic/clinical utility

The following findings regarding total move scores, initiation and execution times, and rule violations were clinically useful:

Total Move Score. This score represents planning and problem-solving performance (Culbertson & Zillmer, 1998), thus problem solving efficiency. Three of the studies (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Solanto et al., 2007) found statistically significant group differences ($p < 0{,}001$; $p < 0{,}02$ and $p<0{,}05$ respectively), in the Total Moves Score between the clinical (ADHD and TBI) and normal samples (typically

developing children). In three studies (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Solanto et al., 2007) the ADHD and TBI-groups executed significantly more extra moves (Total Moves) in solving the test items [(Culbertson and Zillmer (1998) indicated 7–9 years: M = 86,9; 10–12 years: M = 63,7); (Solanto et al. (2007) indicated Combined ADHD group: M = 89,60 and Predominantly Inattentive ADHD group M = 95,90)]. Solanto et al. (2007) reported that the ADHD groups arrived at the correct solution in a less strategic and less efficient manner than their matched normal cohorts. Marton (2008), found that the overall moves were similar for all children when comparing children with specific language impairment (SLI) to typically developing children ($p = 0,72$; $d = 0,1$). However, the SLI-group made more incorrect moves than did the typically developing group (Marton, 2008).

Total Initiation Time. It was suggested that shorter initiation times are associated with less thorough planning of overall schema and sub-goals (Donders & Larsen, 2012). Two studies (Donders & Larsen, 2012; Marton, 2008) found significant differences between TBI and SLI-groups ($p < 0,0002$ and $p < 0,01$ respectively), spending significantly less time thinking and planning ahead and thus having shorter initiation times than controls. This indicates TBI and SLI children employ more impulsive behaviour and less strategic preview of the task. Therefore it indicates poorer prospective memory in children with TBI and SLI (Donders & Larsen, 2012; Marton, 2008).

Total Execution Time. Shorter execution times indicate more efficient executive planning while holding sub-goals in spatial working memory (Donders & Larsen, 2012). Two studies (Donders & Larsen, 2012; Solanto et al., 2007) found that the ADHD and TBI-groups took significantly longer ($p < 0,0001$ and $p < 0,01$ respectively) than controls to complete the test items, which indicates less efficient plan execution. Marton (2008) found no difference in execution time between children with SLI and normally developing peers ($p = 0,13$; $d = 0,43$).

Total Time Violations. Culbertson and Zillmer (1998) found that the ADHD group of 7–9 years differed significantly ($p < 0,007$) from the normal children sub-group, in that they worked significantly slower, while the older ADHD group of 10–12 years approached significance in committing a greater number of Total Time Violations ($p < 0,06$) than the normal children age cohorts (Culbertson & Zillmer, 1998). Marton (2008) found almost identical scores between SLI and normal controls with regard to Total Time Violations ($p = 0,97$; $d = 0,01$).

Total Rule Violations. Three of the studies (Culbertson & Zillmer, 1998; Marton, 2008; Solanto et al., 2007) revealed a group effect with clinical groups (ADHD, SLI and TBI) exhibiting more basic rule violations more often compared to the performance of control groups. Culbertson and Zillmer (1998) reported $p < 0,001$ (7–9years) and $p < 0,03$ (10–12 years), Marton (2008) reported $p < 0,001$ and Solanto et al. (2007) reported $p < 0,01$.

Classification accuracy. Culbertson and Zillmer (1998) indicated that the TOL^{DX} demonstrated appropriate classification rates to support its clinical utility in children with ADHD (overall classification rates 64%). The findings of Donders and Larsen (2012) indicated that the TOL^{DX} has acceptable clinical utility in the context of a more comprehensive neuropsychological evaluation of adolescents with TBI. Furthermore, the classification rates were found to be acceptable for individual diagnostic decisions, particularly when utilised in conjunction with other measures of neuropsychological functioning (Culbertson & Zillmer, 1998). The results in Culbertson and Zillmer's 1998 study indicate that the measure is sensitive and highly specific to ADHD with poor TOL^{DX} performance predicting the presence of ADHD 9/10 times (90%). In Donders and Larsen's 2012 study, the overall classification accuracy was 69,77% correct in assigning individuals to the TBI group versus the control group (sensitivity of 72,09% and specificity of 67,44%). It was suggested that the TOL^{DX} is sensitive to the severity of TBI and can distinguish

adolescents with TBI from neuropsychologically healthy individuals with reasonable accuracy (Donders & Larsen, 2012).

The findings by Donders and Larsen (2012) suggest that a good neuropsychological evaluation of executive functioning should include laboratory and rating scale data, and then integrate these with all other available information to optimise diagnostic accuracy. Groups are best differentiated by ratings, observations and laboratory tests (Solanto et al., 2007).

Measuring different aspects of executive functioning. Several scoring dimensions reflect different aspects of executive planning and problem solving (Culbertson & Zillmer, 1998). In Donders and Larsen's 2012 study, the TOL^{DX} was covaried with the results from a parental rating measure and no covariance was demonstrated ($p > 0,31$), possibly indicating that the instrument measures different aspects of executive functioning. To date there is no clarification on the relationships among factors such as executive functioning, attentional control and visual-spatial working memory (Marton, 2008).

Evidence that the TOL^{DX} is a valid and reliable measure in children

Reliability. Only one article (Culbertson & Zillmer, 1998) reported on the reliability of the TOL^{DX}, namely a reliability coefficient of $r = 0,81$; $p < 0,005$ for the Total Move Score, which is within the moderate to high range indicating that it is relatively stable over time. The temporal reliability coefficient of the Total Time Violations score ($r = 0,79$; $p < 0,005$) was at a moderate level indicating that time violation performance remains relatively constant over time (Culbertson & Zillmer, 1998) – thus they do not work faster. Culbertson and Zillmer's 1998 findings indicated that the Total Rule Violations scores, however, were particularly susceptible to change over time ($r = 0,42$; $p < 0,05$). The test-retest reliability of the TOL^{DX} was found to demonstrate suitable stability over a two-week period (Culbertson & Zillmer, 1998). With the TOL^{DX} version of the measure, the specific and detailed nature of

the administration and scoring reduces the examiner differences in administration and scoring that could attenuate the reliability of the measure (Culbertson & Zillmer, 1998).

Validity. Two studies reported on the criterion validity of the TOL^{DX} (Culbertson & Zillmer, 1998; Donders & Larsen, 2012). The criterion validity was supported by significant differences in performance of clinical groups (ADHD and TBI) compared to normal/control groups across the scoring variable, as already reported above (Culbertson & Zillmer, 1998). Donders and Larsen (2012) found that the Total Initiation Time and the Total Execution Time were the variables that showed the clearest criterion validity.

Evidence that the TOL^{DX} is able to differentiate among different age levels

Only Culbertson and Zillmer (1998) incorporated developmental comparisons into their findings.

Total Move Score. Culbertson and Zillmer (1998) indicated a significant decrease in Total Move Score by increasing individual age levels for both normal and ADHD- groups ($p < 0,02$ and $p < 0,0001$ respectively). They further demonstrated that age-related score differences are evident with older children (10–12 years of age), who achieved lower raw move scores than younger (7–9 years of age) cohorts from both groups. This indicates greater proficiency in planning ahead and plan implementation with increasing age.

Total Rule Violations. Culbertson and Zillmer (1998) found that normal children did not differ in the number of rule violations as a function of age ($p < 0,5$); however, it was clearly observed in the ADHD group. Their ADHD group demonstrated a significant reduction in rule violation by age ($p < 0,0002$). They concluded that older ADHD children are more proficient in guiding planning and problem solving via verbal mediation or internalised rules, although they still perform more rule violations than normal peers.

Total Time Violations. Culbertson and Zillmer (1998) found that mean Total Time Violations scores were found to decrease significantly ($p < 0,009$) as a consequence of

increasing age. It was found that younger normal children (7–9 years of age) needed significantly more time (M = 450,1 s) to solve test items compared with older cohorts (10–12 years of age) (M = 318,0 s), thus older children had significantly less time violations than younger children indicating that they work faster as a result of increasing age (Culbertson & Zillmer, 1998). This implicates greater executive efficiency as the primary determinant of improving time performance (Culbertson & Zillmer, 1998).

Limitations of the TOL^{DX}

No reliability studies have been done with normal children to determine if comparable or improved levels of stability are evident (Culbertson & Zillmer, 1998). The heterogeneity of the ADHD sub-types and the comorbid symptom patterns represented in the ADHD sample may have attenuated the sensitivity and negative predictive rates of the measure (Culbertson & Zillmer, 1998). There is only one study that could be found to demonstrate that the TOL^{DX} is sensitive to severity of TBI (Donders & Larsen, 2012). In one study (Solanto et al., 2007), the results failed to replicate previously reported differences between clinical and control groups. Due to the small number of ADHD females, gender by age group contrasts were not computed, and thus we cannot ensure that gender effects were not evident (Culbertson & Zillmer, 1998). Three of the studies (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Marton, 2008) were demographically representative of the US population and demographic variables such as socioeconomic status, race, and geographical location were not controlled for. Only one of the studies (Solanto et al., 2007) used a sample that was diverse with respect to socioeconomic characteristics. The sample sizes utilised were relatively small and may not have provided sufficient power to find significant differences between groups (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Marton, 2008; Solanto et al., 2007).

The TOL^{DX} warrants cross-validation with independent samples of clinical and control groups (Culbertson & Zillmer, 1998). Comparisons in terms of variables could not be made due to a lack of previous investigations reporting on variables (Donders & Larsen, 2012). Only one study (Solanto et al., 2007) accounted for whether or not the participants were medication naive to all psychotropic drugs.

In the study by Solanto et al. (2007) the researchers elucidated the facts that previous studies on the TOL^{DX} purporting to find differences failed to covary for IQ, and they did not systematically exclude children with comorbidities.

Discussion

To date, a large number of studies have been conducted on various topics around executive skills and functioning. However, only four articles Culbertson and Zillmer (1998), Donders and Larsen (2012), Marton (2008) and Solanto et al. (2007) were identified as complying with the eligibility criteria of this study. In these four articles, the picture emerged that the TOL^{DX}: (1) has diagnostic/clinical utility; (2) is a valid and reliable measure in children; (3) is able to differentiate among age levels; and (4) has certain limitations. It is important however to note that no conclusive deductions can be made from these four articles regarding the appropriateness of the TOL^{DX} for use in children, as variables such as comorbidities, intelligence, age, gender, ethnicity, level of education and medication naivety were not accounted for.

With this in mind, key findings will be discussed. The TOL^{DX} appears to have important implications for clinical and diagnostic utility with regards to children with ADHD, TBI and SLI. When the performance of normal and clinical children on aspects such as Total Move score, Total Initiation Time, Total Execution Time, Total Time Violations and Total Rule Violations were contrasted, normal children consistently exhibited statistically

significant better performance across the scoring variables (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Solanto et al., 2007). These findings are in line with research by Papadopoulos, Panayiotou, Spanoudis, and Natsopoulos (2005) who found that deficits in planning and plan implementation discriminate well between normal and ADHD children. Aguiar, Eubig, and Schantz (2010) further concurred that ADHD children perform more poorly in planning tasks when compared with normal children. Planning impairments and deficits in efficient problem solving were demonstrated by Shum et al. (2009) and Unterrainer and Owen (2006) using the Tower of London with frontal lobe patients. The results thus indicated that the TOL^{DX} demonstrated acceptable and appropriate classification accuracy and clinical utility, particularly when used in conjunction with other neuropsychological measures to optimise diagnostic accuracy (Culbertson & Zillmer, 1998; Donders & Larsen, 2012). The results furthermore elucidated that children diagnosed with ADHD, TBI or SLI have more difficulty with controlled attention and simultaneous goal maintenance than their control peers (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Marton, 2008; Solanto et al., 2007). The clinical groups appeared to perform more poorly in observational measures of motor impulsivity while performing cognitive tasks, as well as in visual-spatial working memory when engaged in planning (Solanto et al., 2007). Poorly planned and disorganised behaviour (working slowly and being impulsive, which include deficits in information processing speed and specific deficits in spatial working memory) are a major detriment to both academic and social success in children, which can be measured on the TOL^{DX} (Culbertson & Zillmer, 1998; Donders & Larsen, 2012). Findings suggest that a weakness in executive function and attentional control has a great impact on verbal and visuo-spatial processing and working memory in children with SLI, and thus possibly in children with other diagnoses (Marton, 2008). This finding of the study is supported by previous research that suggests that the TOL^{DX} measures aspects of ability not tapped by

other measures. By assessing executive concept formation, executive problem-solving, and prospective memory, this measure provides supplementary information on individual functioning (Culbertson & Zillmer, 1998; Riccio, Sullivan, & Cohen, 2010; Riccio et al., 2004).

Secondly, the TOL^{DX} appears to be a valid and reliable measure of executive functioning, specifically executive planning and problem-solving abilities in children. Preliminary reliability and validity results support the TOL^{DX} as a valid and reliable measure of executive planning and problem solving (Culbertson & Zillmer, 1998).

Thirdly, the TOL^{DX} appears to be sensitive and capable of differentiating among different age groups in children. The executive planning performance of older children is characterised by greater accuracy, efficiency, and speed of performance (Culbertson & Zillmer, 1998). A significant age-related difference in scores indicates increased executive planning and problem-solving abilities (Culbertson & Zillmer, 1998). A number of researchers have looked at the development of executive skills thus supporting the current reviews findings in that they have proven that executive functions rely heavily on the prefrontal cortex and the development thereof, with the development being a protracted process starting in infancy and continuing into adolescents and even early adulthood (V. Anderson, 2001; Chevignard, 2009; Snyder, 2013). A number of studies report the parallels between the continued maturation of the frontal lobe and the emergence of executive skills (e.g. P. Anderson, 2002; Diamond, 2013; Diamond & Goldman-Rakic, 1989). Steinberg (2008) suggested that the progressive capacity to make mature decisions lends itself to developmental gains in cognitive control with increasing age. Giedd (2008) predicted, given that the brain regions involved in executive functions reach structural and functional maturity in adolescents, optimal performance on the TOL will only be attained in late adolescents or early adulthood. The TOL^{DX} implicates greater executive efficiency as a primary determinant

of improved performance on the task (Culbertson & Zillmer, 1998). It is perhaps important to note that the TOL^{DX} is a good measure for use in younger children due to its brevity, novelty and game-like nature (Culbertson & Zillmer, 1998).

Limitations

Finally, some important limitations were brought to light. To date, no reliability studies with normal children could be located, and consequently comparable levels of stability on the TOL^{DX} could not be determined (Culbertson & Zillmer, 1998). The clinical samples used in all the studies failed to covary for comorbidities. Only one study made use of a demographically diverse sample (Solanto et al., 2007). The gender by age group contrast was not computed due to the small number of female participants, and thus gender effects remain unknown (Culbertson & Zillmer, 1998). Relatively small sample sizes were utilised, and therefore their results may not have yielded sufficient evidence to indicate a significant difference among groups (Culbertson & Zillmer, 1998; Donders & Larsen, 2012; Marton, 2008; Solanto et al., 2007). The TOL^{DX} needs cross-validation with clinical and control groups (Culbertson & Zillmer, 1998).

Due to the multicultural and diverse nature of the South African population, neuropsychological testing in South Africa is complicated (Foxcroft & Roodt, 2013). The possibility of soon developing culture-free tests in South-Africa with its culturally diverse population and lack of financial resources, is remote. Instead of discarding existing tests for use in the South African context and embarking on developing totally new tests, Shuttleworth-Jordan already proposed in 1996 that internationally recognised tests should be re-normed. She proposed that effects such as cultural or educational disadvantages be taken into consideration when testing non-American and non-Western participants. Consequently, norms need to be obtained for different ages, educational and cultural groups in order to prevent misdiagnosing certain groups. A clear need has therefore emerged for adequate

normative data on neuropsychological measuring instruments in South Africa (D'Amato, Rothlisberg, & Rhodes, 1997). Given the abovementioned concerns and issues, a number of standardised neuropsychological measures have been developed, while others have been used reliably in adult populations. Yet, their appropriateness and reliability have not yet been adequately demonstrated in child populations in South Africa or they do not have South African norms (Batchelor, 1996).

Rapid and systematic reviews are still a new and fast developing field of study, and consequently methods of reviewing have not yet been developed for all areas of science (Gough et al., 2017). At present, there is a deficiency in agreed terminology to describe, discuss and develop methods for reviews (Gough et al., 2017). The requirements will therefore adhere to those set out for systematic reviews, meaning that the research process will be as transparent as possible, enabling researchers to replicate or verify research findings. One of the concerns demonstrated when conducting a rapid review is that the short timeframe runs the risk of introducing bias (Grant & Booth, 2009). Documenting the methodology and highlighting its limitations are important in countering possible bias. It is also important to note that rapidity is not a predictor of quality (Schünemann & Moja, 2015). The risk of human error during the review was minimised by having three reviewers involved in undertaking the research, as recommended by Godfrey and Harrison (2015).

Only four articles complied with all the search terms and eligibility criteria. Generalising the findings of this study is therefore not possible. Also, since no studies done in South Africa were included, it is difficult to form a clear picture of the appropriateness of the TOL^{DX} in the South African context and to make appropriate recommendations in this regard. It is important to state that this study was based on studies of relatively small sample size. As such, it does not represent all data and literature on executive functioning measures and assessments.

Conclusion

To date no reviews have been published on the appropriateness of the use of the TOL^{DX} to measure executive skills in children during neuropsychological assessment, especially not in South Africa. The study was deemed relevant and important because the TOL^{DX}, if found to be effective, could be a valuable short-term solution to the daily challenges faced by South African specialists working with children. From the analysis it was found that the TOL^{DX} as a stand-alone intervention or measure in children has both benefits and limitations. Some of the benefits are related to its diagnostic/clinical utility, evidence of the TOL^{DX} as a reliable and valid measure in children, and the fact that the TOL^{DX} is able to differentiate among different age levels. The limitations revealed by the current study include a lack of demographic heterogeneity in the samples used; the fact that gender effects are still unknown; variables such as comorbidity, medication naivety, and IQ were not accounted/covaried for; and relatively small sample sizes were used. The need for the measure to be part of a larger battery was elucidated, as other important information is required in order to guide intervention and treatment plans for professionals working with children.

The findings from the four studies included in the current review are promising and deserve further exploration in diverse countries such as South Africa in order to see if it will render the same findings. The findings of this study further suggest that the TOL^{DX} is possibly a good measure of executive functioning in children, but when doing normative studies we should be careful to take into consideration all the factors involved as mentioned above.

Recommendations

Although the findings could only be generalised to a limited extent, the results provided new hypotheses that need further exploration. It seems necessary for further

research to include larger random samples. A clear need emerged for adequate normative data on neuropsychological measuring instruments in South Africa to be obtained, in which gender, age, intelligence, ethnicity, level of education, socioeconomic status, comorbidities and medication naivety are controlled or covaried for (D'Amato et al., 1997).

Further exploration should be conducted on the TOL^{DX} in South Africa with specific reference to the clinical and diagnostic utility, its reliability and validity, its ability to differentiate different age levels and thus developmental norms or how the South African population differ in terms of age to other countries and further limitations of the use of the TOL^{DX}, within the South African context. South Africa is in need of norms that are appropriate for use within its diverse population as this will have great benefit for educational and clinical practice alike, thus allowing for better guidance in intervention strategies specifically in respect of executive skills functions and dysfunctions, and contribute to a clearer understanding of executive skills development for children living in South Africa.

Future research may look into comparing the TOL^{DX} scores of children at different stages of development, e.g. at 7 years, then 12 years, then 16 years, or to explore how children from different backgrounds score on the TOL^{DX} e.g. rural versus urban backgrounds.

References: Chapter 2

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CHAPTER 3

CRITICAL REFLECTION

This chapter offers a brief personal reflection on the research process. The entire process of producing and completing a mini-dissertation was challenging to say the least. The writing and completion of the current study took place while I was starting my professional career as an intern clinical psychologist at a psychiatric hospital, together with many personal challenges that arose throughout the year. This complicated and prolonged the research process far beyond my original expectations.

The motivation behind my research topic took shape as I am passionate about South Africa and all it has to offer in its diversity and beauty. One of my favourite aspects of living in South Africa, is the people I am exposed to on a daily basis and the privilege of learning about many different cultures. I am tremendously fervent about the youth of South Africa. I believe they are the future and present the only way to instil change in our country. I believe the only way to make a difference and to see change is to start with our youth – by educating and supporting them. Through my work as a volunteer and mentor of the youth and underprivileged I have witnessed first-hand the lack of resources available to these people. This lack desperately needs attention. I have had personal experience in seeing that South Africans, especially our youth, do not have the means or resources to grow to their full potential.

As a psychologist living in South Africa, I began to consider the influence of its socio-political history. In the past, research was based only on educated white people, and this has remained unchanged to this today. Therefore, a great deal of research is still needed in this regard. It is for this reason that I believe that being a clinical psychologist in South Africa requires input into research of cultural fairness by using methods and approaches that are suitable for a variety of races and cultures. Cultural barriers need to be addressed while

respecting and maintaining people's culture. In recent years mental health has become a priority in South Africa, and yet it is still not receiving the attention it so desperately deserves. Currently, there are a limited number of people receiving psychological services, not to mention neuropsychological services, with the poorer communities receiving none. South Africa is in desperate need of professional introspection and modification in the psychology profession. We need to incorporate culture-specific practices that address the racism and sexism that still plagues the industry. We furthermore need to ensure that the services of clinical psychologists are accessible to those so desperately in need.

With this in mind, when my original research topic fell onto my plate it seemed the perfect opportunity to implement all my ideas on making changes in terms of psychology services in South Africa in that this research could aid in the development of appropriate measures for use in the South African context. At the start of this research process my research supervisor and I decided to join a larger project that was underway and lead by Sharon Truter of Neuropsychology SA. This project entailed collecting norms for the NEPSY-II in Gauteng and other provinces in South Africa. This soon became an overwhelming topic for a mini-dissertation, as the implications for approval by ethics committees of North-West University and the National Department of Education came to light due to the fact that this research involved child participants. This was not the only hurdle as, upon inspection of the NEPSY-II, we soon realised that to administer this assessment could take up to three hours for one child and one hundred children had to be tested. This was not feasible given the expected timeframe for completing for a mini-dissertation. Thus, our next point of call was to change our focus from the NEPSY-II to the Tower of London-Drexel University, 2nd Edition (TOL^{DX}).

As the year went by, reality began to sink in regarding the limited time left to complete this study. In view of my relocation to Gauteng, testing children in the North-West

Province was no longer feasible. After lengthy discussions and recommendation by both my supervisor and co-supervisor it was finally concluded that a rapid review was the best, fastest and most relevant way forward.

This was the first time I conducted a rapid review and as such the first months of the process entailed extensive reading and research on how to carry out and complete a rapid review. At the start I was unsure of myself; this is where my study leaders played a pivotal role in guiding and motivating me to persevere. It is important to note that being located in Gauteng, far away from my study leaders, made communication difficult and frustrating at times, and seemed to add to the time required to complete this mini-dissertation. However, each challenge that arose taught me something new about myself and other people, which I feel is important in terms of my personal growth.

This study has elucidated the fact that many studies in the past tried to define and focus research on the brain and neuropsychological assessments, but few focused on the TOL^{DX}. It also brought to light the limited research available in the South African context.

The relevance of this study became clear to me while working in a psychiatric hospital, specifically in the adolescent unit. I was able to work with and see first-hand the struggles that psychologists face in South Africa in terms of language barriers; the complexity of the cases; and the diversity of the patients in terms of race, culture, gender, and level of education. Using assessments created and standardised for first-world countries became somewhat irrelevant and at times difficult to work with in this specific context. I can now understand how the improvement and standardisation of assessment measures in countries such as our own will impact on therapeutic, supportive, education and intervention plans and goals for children, thus ensuring that they are able to reach their full potential.

Bearing in mind that this study was explorative in nature, it indeed highlighted direction for future studies. In the current study no articles were found that had been

conducted in South Africa. This in itself indicated the lack of research in this context regarding this topic, and the need for future research in South Africa was made clear. This study has made a positive contribution in terms of highlighting the need for more research to be conducted in South Africa. Of great importance is that research pertaining to children living in South Africa should be conducted, as research on this specific topic is extremely limited.

Conclusion

The research process was a rollercoaster ride with many ups and downs, tears and joy. The contribution of this study was to identify possible shortfalls in using assessment measures originally developed and standardised using adult populations, whilst also indicating the need for standardisation of neuropsychological assessment in child populations, specifically in countries where the level and standard of education vary greatly. I was able to learn about a topic that I am passionate about and that has value in my own life. While attempting to remain unbiased and transparent, as well as report trustworthy results, the aim of improving neuropsychological assessment measures in countries such as South Africa was realised. The future directions and recommendations of the current study may aid in the development of and research on interventions, assessment measures and assessment batteries that will be appropriate for use in children, specifically children living in South Africa. I feel as though I have made a positive contribution, however small, to research in South Africa.

I shall end with a quote that I feel encompasses my experience with the topic. "The relationship between culture and development should be clarified and deepened in constructive and practical ways."

– *UN World Commission on Culture and Development Report*

Appendix A: Critical appraisal

#	Authors and publication date	1. Is the study relevant to the research question & aims of our study?	2. Is the problem statement & aim of the study made clear?	3. Was appropriate methodology used?	4. Was a random sample or appropriately motivated non-random sample used?	5. Are the results of the study clearly indicated?	6. Are the results of the study clearly & appropriately interpreted?	7. Are clear & appropriate conclusion & recommendations provided?	8. Compliance with version TOL^{DX}	
1	Asato, M.R., Sweeney, J.A. & Luna, B., 2006	X	✓	✓	X	✓	✓	X	X	Exclude
2	Corbett, B.A., Constantine, L.J., Hendren, R., Rocke, D. & Ozonoff, S., 2009	X	✓	✓	X	✓	✓	✓	X	Exclude
3	Culbertson, W.C., & Zillmer, E.A.,1998	✓	✓	✓	X	✓	✓	X	✓	Include
4	D'Agati, E., Cerminara, C., Casarelli, L., Pitzianti, M. & Curatolo, P., 2012	X	✓	✓	✓	✓	✓	✓	X	Exclude
5	Desco, M., Navas-Sanchez, F.J., Sanchez-González, J., Reig, S., Robles, O., Franco, C., Guzmán-De-Villoria, J.A., García-Barreno, P. & Arango, C., 2011	X	✓	✓	✓	✓	✓	✓	X	Exclude
6	Dias, N.M. & Seabra, A.G., 2012	X	✓	✓	✓	✓	✓	✓	X	Exclude
7	Donders, J. & Larsen, T., 2012	✓	✓	✓	X	✓	✓	✓	✓	Include
8	Hartman, E., Houwen, S., Scherder, E. & Visscher, C., 2010	X	✓	✓	✓	✓	✓	✓	X	Exclude
9	Hartman, E., Smith, J., Houwen, S. & Visscher, C., 2017	X	✓	✓	✓	✓	✓	✓	X	Exclude
10	Jacobs, R. & Anderson, V., 2002	X	✓	✓	✓	✓	✓	✓	X	Exclude
11	Kaller, C.P., Rahm, B., Köstering, L. & Unterrainer, J.M., 2011	X	✓	✓	X	X	X	✓	X	Exclude
12	Baker, K., Segalowits, S.J. & Ferlisi, M., 2001	X	✓	X	✓	✓	✓	X	X	Exclude
13	Lehto, J.E., Juujarvi, P., Kooistra, L. & Pulkkinen, L., 2003	X	✓	✓	✓	✓	✓	X	X	Exclude
14	Marton, K., 2008	✓	✓	✓	X	✓	✓	✓	✓	Include
15	Schurink, J., Hartman, E., Scherder, E.J.A., Houwen, S. & Visscher, C., 2012	✓	✓	✓	X	✓	✓	✓	X	Exclude
16	Solanto, M.V., Gilbert, S.N., Raj, A., Zhu, J., Pope-Boyd, S., Stepak, B., Vail, L. & Newcorn, J.H., 2007	✓	✓	✓	X	✓	✓	✓	✓	Include
17	Zinke, K., Fries, E., Altgassen, M., Kirschbaum, C., Dettenborn, L. & Kliegel, M., 2010	X	✓	✓	X	✓	✓	✓	X	Exclude

Appendix B: Declaration by language editor

I, Mathilde Williams, hereby declare that I am a professional language practitioner and that I conducted a language edit of the mini-dissertation, *The appropriateness of the Tower of London^{DX} to measure executive skills in children during neuropsychological assessment: a rapid review*, submitted by Tahnita Monteiro in partial fulfilment of the requirements for the degree *Master of Science* in *Clinical Psychology* at the Potchefstroom Campus of the North-West University.

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Mathilde Williams

24 March 2018