EXPLORATION OF COMPUTERISED AUTOMATIC PROCESSING TASKS AND THEIR USE IN DIGITAL PSYCHOLOGICAL HEALTH INTERVENTIONS IN REAL-WORLD SETTINGS AMONGST ADULTS

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Abstract

Introduction: Digital psychological health interventions, targeting both behaviour change and mental health disorders, have shown promising results at creating positive change in a variety of health areas. These interventions are based on dual-process theories, which propose that the brain uses two types of thinking to influence behaviour: automatic processing and reflective processing. Automatic processing is fast, immediate, non-conscious, and unintentional. Reflective processing centres around logical reasoning; it is slow, step-by-step, voluntary and intentional. Most health interventions tend to solely target the reflective system; even though repeated laboratory testing has found behaviour can be influenced via targeting automatic processing pathway. This happens through conditioning; which involves pairing a stimulus that naturally elicits a response with one that does not until the second stimulus elicits a response like the first (39).

However, there is a lack of translation of automatic processing tasks into real-world settings and a lack of consolidated evidence on how effective these tasks are in a real-world setting. Further, automatic processing tasks are often described as 'boring' by participants. Having an enjoyable experience could play a significant role in amplifying the conditioning effects of automatic processing tasks. Enjoyment can be increased via gamification, which uses gaming style elements (rewards, points and leader boards) to increase engagement.

This thesis aims to further investigate the use of automatic processing tasks in digital health interventions in real-world settings and address the gaps identified by the

completion of two studies. Study 1 will address the lack of consolidated evidence of automatic processing tasks in real-world settings by way of a scoping review, and study 2 will explore the role of enjoyment in contributing to the effectiveness of automatic processing tasks by evaluating the role of enjoyment as a moderator in an effective gamified automatic processing app called 'Flex.'

Methodology: Study 1 followed the methodologies proposed by Arskey and O'Malley (2005), and Colquhoun (2016) for scoping reviews. A study protocol highlighting search strategy and inclusion and exclusion criteria was developed before conducting the review. Study 2 was nested within a pilot randomised control trial (RCT) of a gamified automatic processing smartphone app called 'Flex'. The RCT found, that at 24-hour follow-up, there was a significant between-group effect such that people in the Flex experimental group had more favourable automatic associations of physical activity than those in the Flex control group. Our nested study was interested in further exploring this association, by examining if the moderator 'enjoyment' was responsible for the increase in effectiveness of automatic processing of physical activity stimuli. This was done by evaluating enjoyment through a validated survey.

Results: Study 1: 4,038 studies were found for possible inclusion into study 1; however, only 14 studies met inclusion/exclusion criteria. Attentional bias modification tasks were the most commonly used (n=7). The review concluded that use of smartphone technology to deliver interventions was increasing, but there were mixed findings of effectiveness automatic processing tasks. There was also preliminary evidence for positive effects of gamification. Study 2 found that automatic processing of physical activity stimuli in the Flex app was not impacted by enjoyment as a

moderator and that enjoyment did not contribute to amplifying the conditioning effect observed in the RCT.

Conclusions: This thesis found that there were encouraging real-world results for the use of automatic processing tasks to influence people's attitudes. The first of these two studies found that there was some evidence of automatic processing health interventions being successful at changing people's automatic associations towards targeted stimuli in real-world settings. This is promising given that the majority of studies into these tasks have occurred in a lab-based setting and highlights the translational potential of these tasks into the real-world.

In terms of why some of these tasks did not work, one possible reason could be due to the repetitive nature and lack on engagement of these tasks. The second study found that enjoyment was not a moderator for the positive associations observed in the RCT. However, encouraging process evaluation results provided insights into participant experience of the app and what elements participants found enjoyable and frustrating. This thesis has been able to contribute to the developing area of automatic processing tasks in a real-world setting. We have been able to highlight that this field, to-date, is still very small but developing and with further research, particularly around increasing engagement, these tasks could provide an innovative solution for improving existing health interventions.

Declaration

I, Harshani Jayasinghe Pedige, declare that this thesis does not incorporate without acknowledgment any material previously submitted for a degree or diploma in any university and that to the best of knowledge it does not contain any materials previously published or written by another person except where due reference is made in the text. I also certify that no part of this work will be used in a submission in my name, for any other degree in any other tertiary institution without the prior approval of The University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Harshani Jayasinghe Pedige

24th of June 2019

Publications and Presentations

The following two papers have been prepared from this thesis as a manuscript for submission to Journal of Medical Health Research mHealth and Journal of Behaviour Therapy and Flex experimental Psychiatry:

1. **Jayasinghe H**, Short CE, Merkin, A, Braunack-Mayer, Hume C. A scoping review of evidence regarding automatic processing tasks used in digital health interventions in real-world settings.
2. **Jayasinghe H**, Short CE, Hume C, Braunack-Mayer A, Rasera M, Rebar AL. Enjoyment as a moderator on automatic processes towards exercise in gamified 'Flex' App in a Randomised Controlled Study.

The following conference presentations resulted from this thesis:

Oral:

1. **Jayasinghe H**, Short CE, Hume C, Braunack-Mayer A, Rasera M, Rebar AL. Rebar. Moderator analysis of enjoyment on FLEX app and automatic evaluations towards exercise. SA Population Health Conference, October 2018.

   Poster:

2. **Jayasinghe H**, Short CE, Hume C, Braunack-Mayer A, Rasera M, Rebar AL. Moderator analysis of enjoyment on FLEX app and automatic evaluations towards exercise. International Journal of Behavioural Nutrition and Physical Activity, June 2019.

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"Do the best you can until you know better. Then when you know better, do better. '-

Maya Angelou

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Thesis structure and Outline

This ‘thesis by publication’ is composed of an introductory background chapter, two studies presented as stand-alone manuscripts and a final chapter providing discussion and conclusions. The two manuscripts presented in this thesis relate to systematic and evidence-based development and evaluation of automatic processing tasks used for digital psychological health interventions in real-world settings by adults. A synopsis of the thesis is provided below.

Chapter 1 provides a brief overview of digital psychological health interventions and their use in health promotion efforts to combat chronic, behavioural and mental health outcomes. It provides a description of how automatic processing tasks are a promising type of digital psychological health interventions that can be successfully used to influence health outcomes.

Chapter 2 presents the results of a systematic scoping review examining the efficacy of automatic training tasks, types of training tasks commonly used, mode of delivery and impacts of gamification on automatic processing tasks among adults. The review highlights that digital automatic processing tasks are being increasingly delivered via online tools such as websites and apps in real-world environments, and have potential to make a positive impact on influencing health conditions. It also provides insights into the types of automatic processing tasks that might be most effective for adult populations as well as engagement strategies that might make these tasks more effective. Recommendations for future investigations include: designing interventions

incorporating both elements of dual-process theory, including a behavioural measure in automatic processing interventions and incorporating the use of gamification.

Chapter 3 presents the results of a moderator analysis, which was nested among a randomised controlled study evaluating an automatic processing app, called ‘Flex’ that was designed to increase automatic processing towards physical activity stimuli. The study found that at the 24-hour follow-up period there was a significant effect such that those in the Flex experimental group had increased automatic processing towards physical activity stimuli. The moderator analysis sought to investigate if enjoyment and the degree to which a participant enjoyed playing the Flex app, influenced how effective the conditioning of the task was. The theory being that those who enjoyed playing the task and had an overall pleasant experience of the app may have a stronger conditioning effect. Process evaluation results of participant experience of the Flex app are also reported and provide insights into how increasing enjoyment through elements such as gamification could improve future health-message delivery.

The final chapter (Chapter 4) summarises the main findings of the thesis and discusses potential avenues for health promotion practice and policy. The strengths and weaknesses of the thesis are also discussed potential avenues and recommendations for future research within the field.

CHAPTER 1

General introduction: Background, rationale and research aims

1.1 BACKGROUND

Each year, the global burden of chronic disease increases, causing premature morbidity and mortality across all socio-economic classes (1). In an effort to prevent the onset and management of chronic diseases, new avenues of research are needed. One promising area are digital psychological health interventions; which in this thesis, is defined as any *'digital intervention targeting preventative illness, chronic disease and mental health disorders.'* Digital psychological health interventions can be delivered via technology such as computers, smartphones, wearable devices, websites and apps (2).

They offer a promising way of supporting self-management of chronic diseases and offer many advantages to traditional interventions. These include being able to tailor to particular characteristics of the user (3, 4) can be cost-effective to develop and maintain compared to traditional campaigns (2) and provide the opportunity to give constant and instantaneous feedback to users (5). Such interventions have been effective at targeting a range of health behaviours and problems including: physical activity (6), diet (6), mental health disorders (7) and cardiovascular disease (8).

Most digital psychological health interventions aim to cause changes to behaviour via targeting intentions to improve health behaviour by focussing on conscious self-monitoring behaviour and goal setting (9,10) Interventions using this approach have shown some evidence of effectiveness; however repeatedly trying to maintain these cognitive processes can be draining on the individual and lead to issues around self-control lapses (11-14). It is not surprising that these types of interventions have been more successful at changing intentions rather than actual behaviour (9, 15, 16).

New lines of thinking have suggested that unconscious patterns of thinking may be able to significantly cause changes to behaviour. This thinking is based upon dual-process theories, which propose that the brain uses two types of thinking to influence behaviour; automatic processing and reflective processing (17-19). Automatic processing centres around intuitive understanding and implicit biases; it is fast, immediate, sub-conscious, and involuntary. Reflective processing centres around logical reasoning and explicit biases; it is slow, step-by-step, voluntary and conscious (20). These two processes happen simultaneously and can often compete against each other creating conflict around final behaviour (20) (18).

During automatic processing, when a stimulus is encountered (eg., a basketball), a network of concepts related to an individual's idea of the stimulus is activated. This activation occurs in the procedural memory, and will result in either the stimulus capturing or repelling the individual's attention (attentional bias), and trigger implicit associations of the stimuli as either 'good' or 'bad'(automatic processes/evaluations) (21, 22). This will result in a behavioural outcome to either approach or avoid the stimulus (approach/avoidance bias) (21). For example, when a person sees a basketball this will trigger a network of concepts in the procedural memory such as 'fun' and 'good' or 'hard' and 'bad' which can lead to a response from the individual to either approach or avoid the basketball (approach-avoidance bias)(21, 23). If the stimuli is perceived as positive it will result in an approach response, whereas if the stimuli is perceived as negative it will result in a avoidance response(23, 24) (Figure 1).

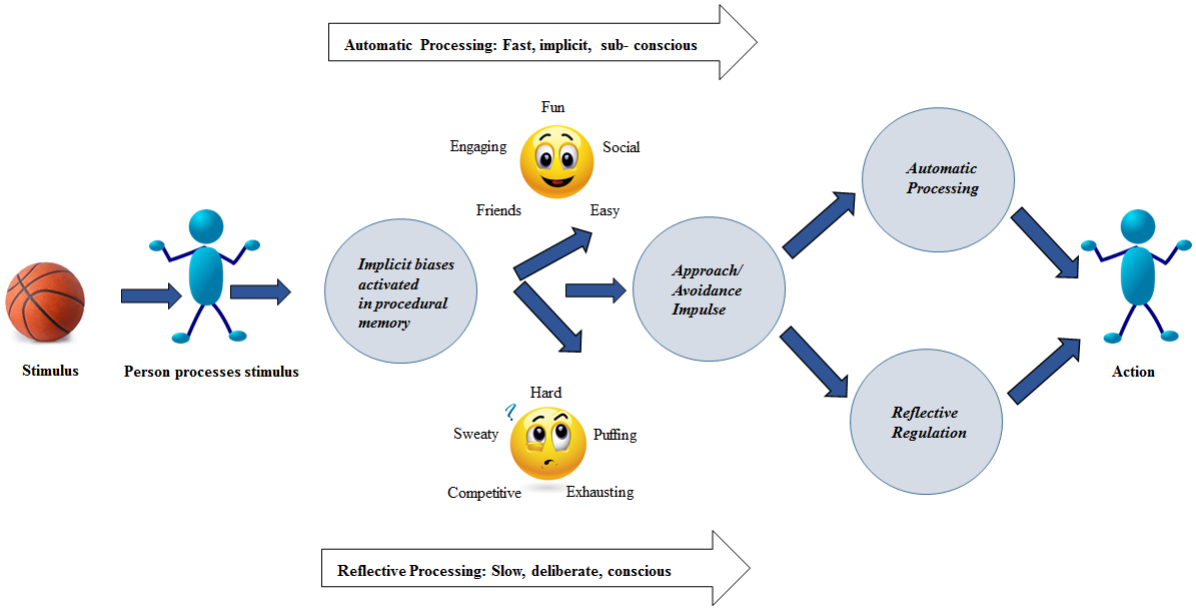

Figure 1: *Example and differences in cognitive processes between automatic processing and reflective processing to a basketball.*

The automatic processing pathway can have a powerful influence on many types of health behaviour(24). For example, some physical activity interventions have shown that participants in an intervention may begin with a conscious intention to adopt physically active behaviour; however, instead during the course of the intervention, they adopt resting behaviour (9, 15, 21). This is because whilst the intention is there, the thought of physical activity or related stimuli will automatically activate an unconscious response from the brain that competes with this conscious intention. In other words, a lack of involvement of the automatic processing pathway can systematically undermine the overall purpose of self-regulation which can strongly influence behaviour (17, 20, 21). Considering, the odds of translatability of intentions to behaviour change is 48% (25), it is evident that there is a large piece of the puzzle that health interventionist are

missing. It is perhaps time to move away from traditional health interventions that solely target explicit motivations and intentions, and incorporate processes targeting unconscious biases and automatic processing.

Automatic processes can be re-trained using cognitive bias modifications, attentional bias modification and evaluative conditioning tasks (26-30). It is important to note that some of these tasks used to re-train automatic processes have evolved from tests originally designed to measure attentional biases (26-30). Cognitive bias modification tasks have been extensively tested in the field of anxiety and depression in laboratory settings (26-30). They work by targeting attentional and interpretative biases away from threat (28). Attention bias usually refers to the tendency to selectively attend to threat stimuli, even when stimuli are irrelevant to current goals and/or when it is in competition for attention with nonthreat stimuli (28). The dot-probe test is often used to assess attentional biases(31). The test involves the presentation of pairs of stimuli; one of which is threatening and one that is neutral. Participants are shown the stimuli simultaneously, one stimulus on either end of a computer screen, for a small amount of time (eg.,500ms), a dot then appears in the place of one former stimulus, and participants are asked to indicate the location of this dot as quickly possible. The computer automatically measures the speed of this reaction. The test is then repeated several times. Quicker responses times to the dot when it appears in the location of threatening stimuli is interpreted as attentiveness to threat(31). Dot-probe tasks can also be used to re-train attentional biases by replacing a targeted probe (designed to change attentional biases) with a neutral or salient stimuli during all cycles of the task (26, 32-35). A commonly used task shows participants a smiling/neutral face alongside an unhappy or angry face; participants are then asked to select the positive image as fast as

possible. The theory is that repeatedly focussing on the positive input rather than negative input will shift the participant's general outlook on life to focus on the positive over the negative(28). Hence, through the repetitive nature of the task, a person's automatic processes can be re-conditioned towards a particular stimulus (28).

Approach/avoidance tendencies are thought to be implicitly influenced by evaluations of how good or bad a stimulus is (36). Approach/avoidance tendencies can be changed by using evaluative conditioning (37). Evaluative conditioning focuses on changes to likability of a stimulus by repetition. Changes in evaluative condition occur when a stimulus is paired with a positive or negative stimuli which eventually leads to stronger biases in people's cognitive processes, which impacts their approach tendencies(36). For example, repeated exposure to the concept of 'good' and the concept of 'physical activity' strengthens approach bias towards physical activity stimuli (36). From here on in, the term 'automatic processing tasks' will be used to refer to the collective tasks; including cognitive bias modification, attentional bias modification and evaluative conditioning tasks, that are used to change people's automatic processes (unconscious biases).

Much of the research into automatic processing and use of automatic processing tasks have been completed in a laboratory setting, in particular in the realm of mental health disorders such as anxiety and depression (29, 38). However, the field is rapidly expanding into other health fields. In addition, they are increasing being delivered in real-world settings via digital psychological health interventions (12, 34, 35).

Weirs et al. (2015) investigated whether different varieties of cognitive bias modification tasks (attention control training and approach-bias re-training) could be delivered completely online and whether these interventions could help reduce drinking habits amongst problem drinkers. Recruitment occurred online using online advertising, a total of 314 participants took part in the intervention which consisted of a pre-test, four sessions of computerised training and a post-test. Participants were randomised into one of four groups: attention control or one of three varieties of approach-bias re-training or a sham-training control condition. Participants in all conditions reduced their drinking, suggesting that integrating cognitive bias modification with online cognitive and motivational interventions could improve results.

Whilst automatic processing tasks have shown capability for changing people's unconscious biases, a common criticism of the tasks is that they are 'repetitive' in nature and are often described as 'boring' by participants (12, 29). This is not ideal in any intervention, but particularly one that focuses so heavily on the use of conditioning; which involves pairing a stimulus that naturally elicits a response with one that does not until the second stimulus elicits a response like the first (39). The overall experience, either enjoyment or frustration, that participants have with the automatic processing tasks may amplify the intended conditioning messages of the automatic processing task. Having either a positive or negative experience with the task, may become associated with the conditioning messages of the tasks. This positive experience with the task, may lead to positive feelings towards the conditioning messages of the task which may result in an amplification of the conditioning messages due to this positive experience being conditioned with the conditioned messages. Conversely, participants experiencing negative feelings such as frustration may be conditioned to associate the frustrating

experiences with the conditioning messages of the task, leading to the opposite conditioning effect as originally intended. For example, if a person playing an automatic processing physical activity game is enjoying the experience, they may begin to associate positive feelings with the game, thereby increasing positive feelings with physical activity and hence strengthening the conditioning effect of the game.

Boredom, or put another way, not having an enjoyable experience may lead to poor study outcomes. Enjoyment is a complex experience, and it likely reflects the intersection of a variety of factors, including cognitive, affective, social and physiological elements (13, 40). If participants are not enjoying a task, it may lead to a lack of efficacy (41), retention (42), poor data quality and may have negative effects on study outcomes(43). Hence, it is important to consider the role of enjoyment of participants when designing automatic processing interventions. One way of increasing enjoyment of automatic processing tasks is to use the emerging field of gamification(13).

Gamification seeks to engage users more by using gaming style elements often seen in games (rewards, points and leader boards) (12, 13, 33, 44-46). Through the use of gamification, enjoyment can be increased via graphics, sound effects, challenging nature and competitiveness of games (44). These aspects can contribute to motivation to keep engaging with the game. Conversely, frustration can also arise during the course of play. This could arise if the games are too challenging or of poor quality and could lead to frustration and disengagement with the game (47-49).

Only a small amount of studies have investigated gamification of automatic processing tasks. Boendermaker et al. (2015), investigated gamifying an existing automatic processing task aimed at influencing youth drinking behaviour. The purpose of the study was to conduct a pilot investigation to see if a) adding gaming elements increased user experience and motivation to use the application, and b) assess the effectiveness of the application to change in alcohol-related memory bias and behaviour change (32). The study consisted of 77 undergraduate students. The gamified task was called 'Cheese Ninja Game.' The aim of the game was to navigate a ninja mouse through a series of hallways and to collect as many good objects as possible while ignoring the harmful objects. Participants were randomly assigned into one of the four groups (the original training task, gamified task, placebo training task and a social-version task) and after the final training session participants completed a questionnaire to evaluate user experience and motivation. The results of the study indicated that the gamifying automatic processing tasks could increase fun and motivation to train using the task (32). However, in terms of the author's primary outcomes, it was found that the gamified tasks did not influence bias score or drinking behaviour (32). In a separate study by Boendermaker et al. (2016), he gamified an existing automatic processing task which aimed to train attention away from pictures of alcoholic beverages called the visual probe task (34). Contrastingly, to his previous study, he found that the gamified automatic processing task did not improve participants motivation to train as compared to the usual un-gamified task (32, 34). From the small amount of studies that exist in the field, there are mixed results to the use of gamified automatic processing computerised tasks(12, 14, 33).

There are significant gaps in the field of automatic processing tasks, these include that the majority of reviews into automatic processing tasks have been limited in their scope; focussing mainly on mental health conditions delivered in laboratory settings, and routinely include studies with children whose brain development is significantly different to adults(50-54). Additionally, the field is growing rapidly with advances in delivery mode and use of gamification; however, there have been mixed findings on effectiveness of adding gamification elements to these tasks to increase engagement, and for those that have found positive associations, gamification elements have not been thoroughly evaluated (32, 33). A consolidation of the literature is needed across all health fields that provides information on how these tasks work in real-world settings amongst adult populations. Hence, a scoping review of health interventions targeted at adults and delivered in real-world settings will be conducted for Study 1 of this thesis.

Additionally, to date, there are no studies in the field investigating the role of enjoyment in contributing to the conditioning effects of automatic processing tasks. Participant boredom is often reported as a negative element of automatic processing tasks due to their repetitive nature. It is known from previous research that enjoyment is linked to efficacy (41), retention (42), poor data quality and may have negative effects on study outcomes(43) in interventions. A further understanding of the role of enjoyment on influencing participants and their outcomes during automatic processing interventions is needed. The second study contained within this thesis is a nested study amongst a randomised controlled trial (RCT) of an automatic process app called ‘Flex.’ This RCT aimed to evaluate changes in automatic processing directly after playing the app and at a 24-hour follow-up point between Flex experimental and a Flex control group. At the 24-hour follow-up point, a significant between-group effect was found such that people

in the Flex experimental group had more favourable automatic associations of physical activity than those in Flex control group. A nested study was an opportunity to further understand enjoyment amongst participants using Flex. We conducted a moderator analysis on the role of amplifying the conditioning messages contained within Flex. A moderator is a variable that affects the strength of the relationship between a dependent and independent variable. Enjoyment was evaluated directly via Fang et al.'s (2010) *'enjoyment of computer game play'* questionnaire and a 12-item process evaluation survey examining user-experience.

1.2 AIMS

STUDY 1 – A scoping review of evidence regarding automatic processing tasks used in digital health interventions in real-world settings.

Aim: To investigate the efficacy of automatic training tasks, types of training tasks commonly used, mode of delivery and impacts of gamification on automatic processing tasks among adults through the process of a literature review.

STUDY 2- Enjoyment as a moderator on automatic processes towards exercise in gamified 'Flex' App in a Randomised Controlled Study.

Overall Aim: To investigate the role of 'enjoyment' as a moderator in contributing to the effectiveness of a gamified automatic processing app called 'Flex.'

Aim 1: Investigate if people enjoyed 'Flex' through use of validated Fang et al. (2010) questionnaire

Aim 2: Assess if enjoyment moderated the effect of conditioning observed at the 24-hour follow-up period in the Flex RCT study

Aim 3: Evaluate the results of the process evaluation survey to provide further insight into people's perception and experience of Flex app.

CHAPTER 2

A scoping review of evidence regarding automatic processing tasks used in digital health interventions in real world settings

Statement of Authorship

Title of Paper	**A scoping review of evidence regarding automatic processing tasks used in digital health interventions in real-world settings.**
Publication Status	☐ Published ☐ Accepted for Publication ☐ Submitted for Publication ☑ Unpublished and Unsubmitted work written in manuscript style
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Principal Author

Name of Principal Author (Candidate)	**Harshani Jayasinghe**		
Contribution to the Paper	Developed protocol, performed search on all databases, extracted data, wrote manuscript and revised manuscript.		
Overall percentage (%)	85%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	14/05/2019

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	Camille E. Short		
Contribution to the Paper	Supervised development of work, helped in data interpretation and helped evaluate and edit the manuscript.		
Signature		Date	16/5/19

Name of Co-Author	Ashley Merkin		
Contribution to the Paper	Assisted in data-extraction and editing.		
Signature		Date	16/05/2019

Name of Co-Author	Annette Braunack-Mayer		
Contribution to the Paper	Assisted in data-extraction and development of protocol.		
Signature		Date	16/05/2019

Name of Co-Author	Clare Hume		
Contribution to the Paper	Supervised development of work, helped in data interpretation and helped evaluate and edit the manuscript.		
Signature		Date	16/5/19

2.1 CONTEXT OF THIS RESEARCH

The chapter describes the first original research arising from this Master's thesis. This study focussed on conducting a scoping review of the existing evidence-base regarding automatic processing computerised tasks designed for health interventions in real-world settings. This scoping review provides further insight into the field at large highlighting the efficacy of automatic training tasks, types of training tasks commonly used, mode of delivery and impacts of gamification on automatic processing tasks amongst adults. This chapter has been presented in the form of a manuscript that will be submitted to JMIR mHealth for publication.

2.2 ABSTRACT

Background: Dual-process theories propose that the brain uses two types of thinking to influence behaviour, automatic processing and reflective processing. Automatic processing is fast, immediate, non-conscious, and unintentional. Reflective processing centres around logical reasoning; it is slow, step-by-step, voluntary and intentional. Most digital psychological health interventions tend to solely target the reflective system even though the automatic processing pathway can have strong influences on behaviour. Laboratory-based research has highlighted that automatic processing tasks can create behavioural change; however, there is a lack of translation of these findings to real-world settings. In addition, there are significant gaps in the field around design, implementation and delivery of automatic processing tasks in real-world settings. The aim of this review was to investigate the current evidence-base around design, mode of delivery, types of training tasks and the efficacy of automatic processing tasks designed for digital psychological health interventions in real-world settings among adults.

Methods: The scoping review methodology proposed by Arskey and O'Malley (2005) and Colquhoun (2016) was applied. A scoping review was chosen due to the novelty of the digital automatic processing field and to encompass a broad review of the existing evidence-base. A study protocol highlighting search strategy and inclusion and exclusion criteria was developed before conducting the review. Electronic databases and grey literature databases were searched with the search terms 'automatic processing,' 'computerised technologies,' 'health intervention', 'real-world' and 'adults'. The search is up-to-date until September 2018. A manual search was also completed on reference lists of included studies.

Results: Fourteen studies met all inclusion criteria. There was a wide variety of health outcomes targeted with the most prevalent being alcohol abuse followed by social anxiety. Attention bias modification tasks were the most prevalent type of automatic processing task, and the majority of tasks were most commonly delivered online via a personal computer. Of the 14 studies included in the review, just under half of them resulted in positive changes to automatic processes.

Conclusion: This is likely the first review to synthesise the evidence for published and grey-literature on automatic processing tasks set in real-world settings targeting adults. Findings were mixed in the field in terms of effectiveness, with 6 out of 14 studies showing significant improvements in automatic processing. Positive results of the studies are promising for real-world implementation of these tasks, however, several studies showed either null or mixed findings. This may have been due to low levels of enjoyment of automatic processing tasks. Future studies should consider increasing enjoyment of automatic processing tasks by incorporating gamification, which uses graphics, visuals and rewards often seen in games to increase participant enjoyment of tasks.

Key Words: Automatic Processing, Computerised Tasks, Health Interventions, Real-world, Adult, Behaviour change

2.3 INTRODUCTION

Digital psychological health interventions, which encompass both behaviour change and mental health, are being increasing adopted to prevent and manage chronic health conditions (2, 55, 56). The digital nature of these interventions make them more accessible as they can be delivered on devices such as smartphones, computer devices and iPads (56). Digital platforms allow the opportunity to circumvent traditional issues faced by existing health interventions; including improving scalability costs, participant experience and providing the opportunity to tailor interventions to individual needs (2, 55, 57).

Digital psychological health interventions are based upon dual-process theories, which in general, propose that the brain uses two types of thinking to influence behaviour (17-19); automatic and reflective processing. Automatic processing is fast, immediate, unconscious, and unintentional (9, 20). Reflective processing centres around logical reasoning; it is slow, step-by-step, voluntary and intentional, such as self-regulatory processes (9, 20). These two types of processes can occur simultaneously and can have concordant or opposing influences on behaviour (9). Dual-process theory highlights that both the reflective and automatic processing pathways need to be targeted to cause changes in behaviour. Most behaviour change interventions tend to target the reflective system, aiming to improve self-regulatory processes such as self-monitoring behaviour and goal-setting(9, 58). According to dual-process theory, automatic processes are thought to drive behaviours in an unconscious way and can systematically interfere with conscious attempts to change behaviour (9, 16). Yet, relatively few interventions target automatic processes (12).

Automatic processes involve attentional biases, approach biases and interpretative biases (56) which can be targeted during health interventions. Attention bias usually refers to the tendency to selectively attend to threat stimuli, even when those stimuli are irrelevant to current goals and/or when it is in competition for attention with nonthreat stimuli (28). Approach/avoidance bias is thought to be implicitly influenced by evaluations of how good or bad a stimulus is (36, 37). Interpretative bias refers to the predisposition to inappropriately analyse ambiguous stimuli as either good or bad (28).

During automatic processing, when a stimulus is encountered (eg., a basketball), a network of concepts related to an individual's idea of the stimulus is activated. This activation of mental networks occurs in the procedural memory and will result in either the stimulus capturing or repelling the individual's attention (attentional bias), trigger unconscious or implicit associations of the stimulus as either 'good' or 'bad'(automatic processes/evaluations) and will result in a behavioural outcome to either approach or avoid the stimulus (approach/avoidance bias) (21, 23). For example, when a person sees a basketball this will trigger a network of concepts in the procedural memory such as 'fun' and 'good' or 'hard' and 'bad' which can lead to a response from the individual to either approach or avoid the basketball (approach-avoidance bias). If the stimuli are perceived as positive it will result in an approach response whereas if the stimuli is perceived as negative it will result in a avoid response (21, 23).

Automatic processes can be re-trained using attentional bias modification, cognitive bias modification and evaluative conditioning tasks(59). Attentional bias modification training, a form of cognitive bias modification, involves repeatedly directing visual

attention away from target stimuli and towards control stimuli (60). The traditional cognitive bias modification task most commonly used focusses on avoidance training. Participants are asked to repeatedly approach or avoid target stimuli and avoid or approach control stimuli(61). These movements may be physical or figurative. During evaluative conditioning target stimuli are repeatedly paired with valanced, typically negative unconditioned stimuli (62). The theory behind these tasks is that repeated exposure to task will condition participants to associate the behaviour they do during the task with the critical stimulus (59).

There is evidence that in a lab-based setting digital interventions in the way of computerised tasks work to change people's automatic processes to specific stimuli (28, 29, 33, 38). Despite the evidence of the importance of this pathway for regulating behaviours, little is known about how automatic processing tasks creates behaviour change in the in a real-world setting, as most of the investigations around the use of automatic processing tasks have been conducted in a laboratory setting(29, 38, 63-65). The majority of reviews into automatic processing tasks have been limited in their scope; focussing mainly on mental health conditions delivered in laboratory settings, and routinely include studies with children whose brain development is significantly different to adults (52, 66, 67).

The field is growing rapidly with advances in delivery mode and use of gamification; however, evidence of efficacy of these features is limited. However, a common criticism of these tasks is that they are often described as 'boring' and 'repetitive' by participants (12, 29). Recently, the field has expanded to make these tasks more enjoyable by drawing on the developing realm of gamification. Gamification seeks to

engage users by using gaming style elements often seen in games (rewards, points and leader boards) to keep users motivated and engaged. A review by Boendermaker's et al. (2015) into the gamified cognitive bias modification highlighted that there were many projects currently in progress, however, of those evaluated thus far; there was not enough evidence to draw any firm conclusions as to efficacy of gamification on increasing engagement of cognitive bias modification tasks. Similarly, Zhang et al. (2018) highlighted that understanding of gamification approaches was crucial in future conceptualization and co-design of gamification attention bias modification interventions.

A consolidation of the literature is needed across all health fields that provides information on how these tasks work in a real-world setting among adult populations. This will provide an evidence-base of effectiveness for short and long-term behaviour change, while also providing valuable insight into how these tasks may be improved (16, 27, 38, 39). Hence, a scoping review of health interventions targeted at adults and delivered in real-world settings will be conducted. The aims of the scoping review will be to investigate the efficacy of automatic training tasks, types of training tasks commonly used, mode of delivery and impacts of gamification on automatic processing tasks among adults.

2.4 METHODS

2.4.1 Scoping Review methodology

Scoping reviews aim to *'map rapidly the key concepts underpinning a research area and the main sources and types of evidence available'* (68). This scoping review sought

to address the question: ‘what is the current evidence-base around design and efficacy of automatic processing computerised tasks designed for health interventions in real-world settings among adults?’ A scoping review was chosen due to the novelty of the digital automatic processing field and in an effort to encompass a broad review of the existing evidence-base. Scoping reviews allow the opportunity to develop inclusion/exclusion criteria during the study selection phase, allow for the inclusion of all types of studies, and extract data regarding key issues and themes, contrastingly to systematic reviews, which are much more stringent with the synthesis of review.

This scoping review followed the framework described by Arksey and O’Malley (2005), who provided a detailed description of how to conduct a methodologically rigorous scoping review. In addition, Colquhoun’s (2014) ‘current best practices for the conduct of scoping reviews’ guidelines were also applied. Arksey and O’Malley’s (2005) methodology comprised of the following steps: (1) identifying the research question; (2) identifying relevant studies; (3) study selection; (4) charting the data; (5) collating, summarizing, and reporting the results. A number of additional recommendations from Colquhoun (2014) were also integrated: development of a protocol before the initial scoping study began, using PRISMA-P, the use of two independent reviewers, use of same inclusion criteria during initial data screening as well as full-text screening and pilot-testing the data-extraction template.

2.4.2 Identifying relevant studies

Selection Criteria

A systematic literature search was created with the assistance of an academic librarian from The University of Adelaide. It was translated into all databases by HJ, and reviewed by the academic librarian. The search was completed using the electronic databases PubMed, Scopus, Embase, Psychinfo, Web of Science, CINAHL, Cochrane Database of Systematic Reviews and Google Scholar. The search was performed in September 2018. Pubmed, Embase, Web of Science and CINALH were chosen for their extensive repository of medical and scientific literature, Scopus was selected to enhance the acquisition of multidisciplinary studies outside of the medical field, Psychinfo was selected due to the psychological basis of the review topic, Cochrane was chosen to identify any existing systematic reviews and Google scholar was searched to identify any studies missed by the databases. A grey-literature search was also conducted to identify any published or unpublished data not found through the initial search. This included electronically searching the repositories holding theses and research papers; Trove, The Grey Literature Report, Proquest, OpenGrey and GreyNet International. Reference lists of all included studies were also manually screened to identify any possible relevant citations. Articles not published in English were excluded. Articles were also excluded if they were published before the year 2000 due to digital expansion in the field of automatic processing predominately occurring after the year 2000. The search strategy created was based on five main components: 1) automatic processing, 2) computerized tasks, 3) health interventions, 4) real-world and 5) adult. Relevant keywords were identified using MeSH and EMTREE terms, synonyms and keywords from relevant articles.

Inclusion Criteria

Inclusion criteria for the study were adults aged over 18 years; designed to be a health intervention (defined as aiming to improve physical or mental health); delivered via a computerised (digital) task; and delivered in a real-world setting (a free living environment, excluding a lab-based environment). Only studies published in English between the years 2000-2018 were included.

The results of the search were uploaded onto Endnote X 7.3.1 and after duplicates were removed was exported into Rayyan. Rayyan is an online tool that has been designed to aid researchers to complete systematic reviews. Rayyan was used by HJ to complete an initial title search screen using the search strategy to determine eligibility. This was followed by an abstract screen of studies using inclusion/exclusion criteria. If eligibility was ambiguous criteria was discussed with other co-authors until a consensus was reached. An eligibility proforma was also used during this process. Articles matching the inclusion criteria were then selected for full-text analysis.

2.4.3 Charting the data

Data extraction occurred using a standardised data extraction template created by the research team, which included fields of: author, year, country, aims of the study, setting and population, participant demographics, details of the intervention and comparators, study methodology, sampling and recruitment, completion rates and intervention details. The extraction template is attached as Appendix 1. HJ, CES, CH and AB all conducted data extraction for the first two publications using the original data extraction template. All reviewers then discussed any iterations the form may need and the

template was changed appropriately to reflect any significant gaps or inconsistencies that arose during this period. Data for all remaining studies were extracted by HJ, with 10% being verified by AM. Any conflicts or concerns during this period was resolved through discussion with the CES and CH.

2.4.4 Collating, summarizing, and reporting the results

The data extraction forms were used to form quick overview summaries of the included studies. First, a descriptive numerical summary was used to create a numerical overview of general study characteristics and then a narrative overview was conducted on the type of automatic processing task used and effectiveness.

2.5 RESULTS

The 'Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)' for the results of the search are presented in Figure 1. The flow chart contains results from the initial search, how many studies were removed due to duplications, study selection and amount selected for full-text study retrieval [Figure 1]. The search is up to date until September 2018, where a total of 4,576 studies were found for possible inclusion [Figure 1]. Of these, 320 were assessed for full-text inclusion, finding that 14 studies met all inclusion criteria. Reasons for study exclusion included being a review paper, irrelevant to the topic area and not being set in a real-world setting.

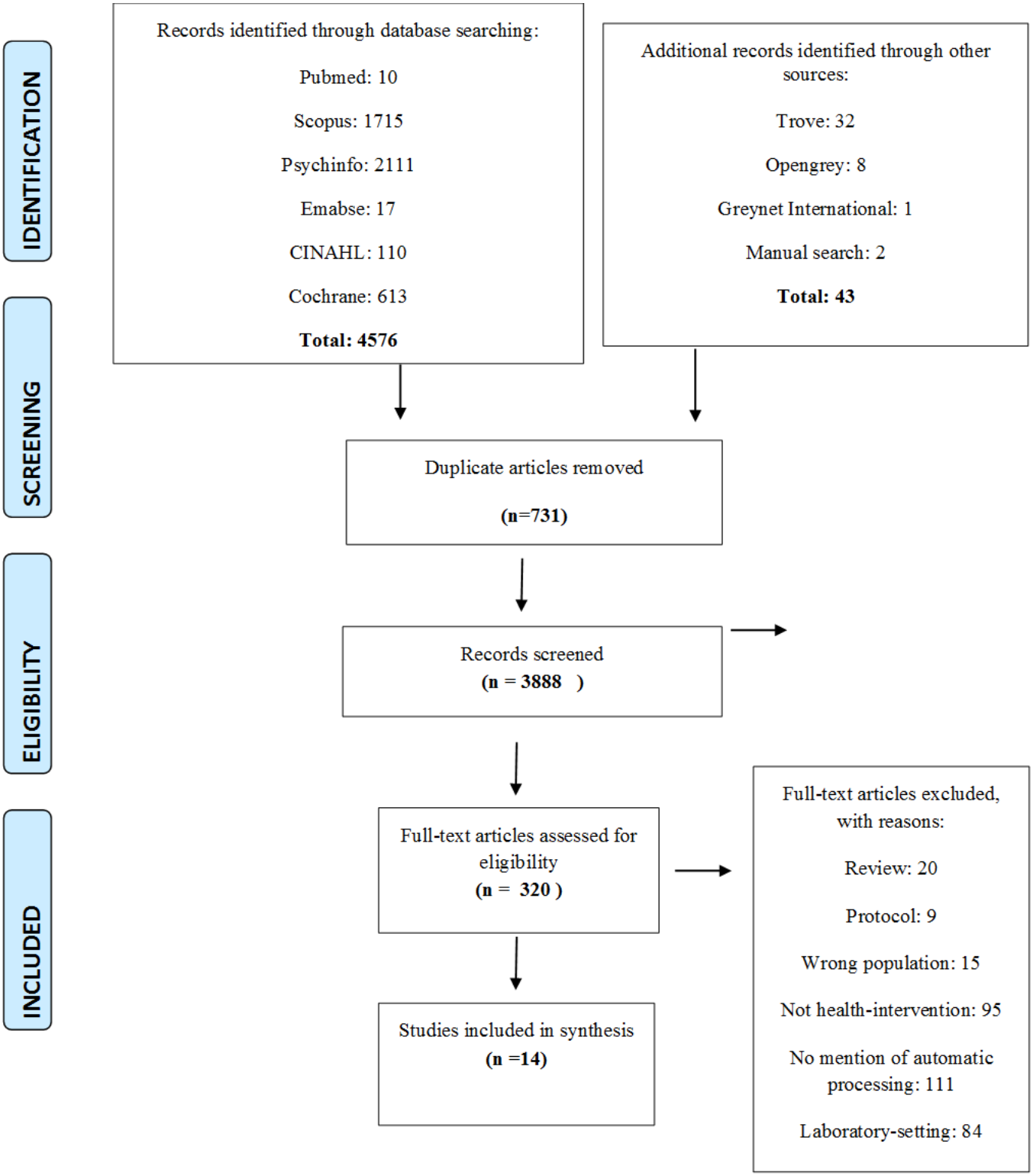


Figure 1: Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)' for the results of the search

2.5.1 General characteristics

General characteristics of the studies including type of study, sample size, country and follow-up are reported in Table 1. The majority of the included studies were carried out in Europe and the United States with six in Europe and five in the United States. One study was also carried out in China and another one in Australia. All of the studies were randomised controlled trials, except one that did not state what the study design was. Sample sizes of the studies varied considerably and ranged from 21-672 participants. Five of the studies targeted automatic processes towards alcoholism (34, 35, 69, 70, 77). Two studies targeted smoking attitudes and behaviour (71, 72). Two studies targeted automatic processes towards anxiety (27, 73) and one targeted automatic processing towards both anxiety and depression (26). Additionally, one study was found for each of the health fields of insomnia (74), self-injurious thoughts and behaviours, attitudes towards homosexuality and self-esteem in gay men and relationship satisfaction in marriages (75).

Table 1: General demographics of included studies (n=14)

Included studies	**Type of study**	**Sample size**	**Country**	**Follow-up**
Robinson 2017(72)	Randomised controlled trial	n=64	United States	14 days
Clarke 2016(74)	Randomised controlled trial	n = 36	Australia	8 days
Yang 2017(73)	Randomised controlled trial	n= 76	China	No follow-up
Fleming 2017(76)	Randomised controlled trial	n=274	United States	No follow-up
Deursen 2015(77)	Cross-sectional	n=437	Germany	No follow-up
De Voogd 2016(26)	Randomised controlled trial	n=340	Netherlands	Baseline measures were taken before training, and then 3, 6, 12 months post training
Enock 2016(27)	Randomised controlled trial	n=429	United States	Pre-test, post-test, one and two month follow ups
Monk 2017(70)	Randomised controlled trial	n=62	United Kingdom	No follow-up
Weirs 2015(35)	Randomised controlled trial	n=615	Netherlands	The first follow-up was one month after the post-test (N = 109, 35%), the second two months later (n=87, 28%).

Boendermaker 2016(34)	Randomised controlled trial	n= 96	Netherlands	4 sessions conducted at least 1 day apart AND 2 week follow-up after session 4
Crane 2018(69)	Randomised controlled trial	n= 672	United Kingdom	The follow-up questionnaire was sent to participants 28 days after downloading the app.
Elfeddali 2016(71)	Randomised controlled trial	n= 475	Amsterdam	A post-training assessment (i.e., manikin and VPT tasks) followed the intervention sessions. An Assessment of continued smoking abstinence followed 6 months after baseline
Franklin 2016(78)	Randomised controlled trial	n= (114 , 131 and 163)	United States	1 month follow-up
McNulty 2017(75)	Randomised controlled trial	n=288	United States	2 weeks

2.5.2 Intervention characteristics

Types of Digital Technology

Table 2 reports on intervention characteristics of the included studies. The type of digital technology most often used to execute the intervention was a personal computer or laptop via a website (n=8) (26, 34, 35, 70, 71, 75-77) followed by use of smartphone app (n=5) (27, 69, 73, 74, 78), one study was delivered on a Personal Digital Assistant device (72).

Table 2: Intervention characteristics of included studies (n=14)

Author	Type of Digital Technology	Real-world setting
Robinson 2017(72)	Hewlett-Packard IPAQ Personal Digital Assistant.	Lab/home
Clarke 2016(74)	Smartphone	Lab/home
Yang 2017(73)	Smartphone	Home
Flemming 2017(76)	Functioned only on desktop or laptop PCs	Online
Deursen 2015(77)	PC or laptop	Online
De Voogd 2016(26)	Computer	Online-school
Enock 2014(27)	Smartphone	Online
Monk 2017(70)	Computer, mobile prohibited	Online
Weirs 2015(35)	Computer	Online
Boendermaker 2016(34)	Computer	Lab/home
Crane 2016	Smartphone app	Online
Elfeddali 2016(71)	Computer	Online
Franklin 2016(78)	Mobile app but can be used on phones, tablets, laptops, and desktops	Online
McNulty 2017(75)	Computer	Lab/home

Use of Dual-Process Theory

Six of the 14 included studies referred to dual-process theory when explaining the theory behind the use of bias modification tasks, and four focussed solely on use of an automatic processing task to change behaviour. A further four studies made no mention of the dual-process theories or any theories guiding their research. One of the studies, Fleming et al. (2017) did not mention dual-process theories but did mention the minority stress model and the cognitive theory of depression guiding their research.

Although several studies referred to dual-process theory, only two of the included studies (69, 77) focussed their interventions on targeting both parts of dual-process theory by targeting both automatic processing and reflective processing pathways. Crane et al. (2018) evaluated module components of an alcohol reduction app called 'Drink Less' to change participant's drinking behaviour. Of the five modules used in the intervention, two were based on dual-process theory: 'cognitive bias re-training', which targeted automatic processes, and 'normative feedback', which targeted reflective motivation. It was found that there was a significant two-way interaction between these two modules on weekly alcohol consumption ($p = 0.03$); indicating that enhanced normative feedback led to a significant reduction in weekly alcohol consumption only when combined with enhanced cognitive bias re-training. Deursen et al. (2015) also examined the relationship in problem drinkers seeking online help to change their alcohol use, hypothesising that executive functions would moderate the relationship between automatic associations and drinking, and that this effect would be stronger in individuals with strong motivation to change. A brief 'Implicit Association Test' was used to test valence and approach associations, while executive (reflective)

pathways were assessed via the readiness to change questionnaire testing motivation, the self-ordered pointing task testing working memory and the Stroop task testing response inhibition. The results of the study provided partial support for the moderating role of motivation in the interplay between automatic processes and executive functions.

Types of automatic processing tasks

Three types of automatic processing tasks were used; attentional bias modifications tasks, cognitive bias modifications task and evaluative conditioning tasks. Attentional bias modification tasks were the most commonly delivered intervention through the use of dot-probe, visual probe and visual search tasks. Cognitive bias modification tasks were delivered via dot-probe test (73), word sentence association paradigms (73), attentional control training, approach bias-retraining (35) and cognitive bias re-training (69). Evaluative conditioning was delivered via evaluative conditioning tasks (75, 79), a stop-signal task and a game-like therapeutic evaluative conditioning task.

Usage

Intervention durations varied considerably between the studies that reported on how long the intervention was delivered for, ranging from the shortest intervention period of 75 minutes to the longest intervention period of 6 weeks. Follow-up periods also varied, and ranged from no follow-up (n=4 studies;(70, 73, 76, 77)) to the longest follow-up period of 6 months (71). All studies delivered at least some of their intervention in a real-world setting with four of studies delivering interventions in a mixed setting (both laboratory and home environments). Some studies reported issues with usage. This included the number of training trials used over sessions being too low preventing the

training from potentially changing attentional biases (34), low training compliance; with some participants dropping out of the study midway effecting overall results and limiting generalisability of findings (26, 35, 69, 72), and having self-selected use and dosage during the intervention; making it hard to determine optimal dosage needed for intervention (78).

Gamification strategies

Three of the included studies incorporated elements of gamification to enhance engagement of their intervention (34, 69, 78). Boendermaker et al. (2016) gamified an existing automatic processing task, which aimed to train attention away from pictures of alcoholic beverages via a visual probe task. He found that the gamified automatic processing task did not improve participant motivation to train as compared to the usual un-gamified task. In fact, some aspects of motivation appeared to deteriorate rather than improve. The other two studies by Crane et al. (2018) and Franklin et al. (2016), both saw positive effects on study outcomes with the use of gamified elements in interventions. However, the effect that gamification had on influencing these outcomes was not investigated, making it difficult to deduce which aspects of gamification produced different effects and overall how effective gamification was.

2.5.3 Acceptability of Interventions

Some studies reported that it was possible that the option to train at home had a negative effect on final results as it may have made participants take the training less seriously (34,77). It was also noted that the web-based nature of the online assessments resulted in issues with standardisation, making it hard to control how measures were completed (77). Large number of measures included in some studies may have also

resulted in participant fatigue (77) and use of similar type of tasks testing different outcomes may have resulted in practice effects which may have affected overall findings.

2.5.4 Effectiveness of Interventions

A detailed description aims, measures and effectiveness of included studies can be found in Appendix 2. Thirteen studies assessed changes in automatic processes, while 11 assessed how changes in automatic processing contributed to changes in behaviour. Of the thirteen studies that assessed changes in automatic processes, five reported a positive intervention effect. Of the 11 studies that assessed behavioural or mental health outcomes, five reported a significant intervention effect. Overall, six studies reported a positive finding in line with hypotheses for at least one outcome assessed.

Three studies reported mixed findings (72, 73, 78). Robinson et al. (2017) found that while the attentional re-training reduced attentional biases for smoking, mixed outcomes were seen for automatic processing affecting actual smoking behaviour. The authors attributed this to participant attrition affecting overall results and the sample being non-treatment seeking participants. During Yang et al's (2017) study three types of cognitive bias modification tasks were tested against each other. The study found that only one type of task, cognitive bias modification interpretation task, was effective; while cognitive bias modification attention task and attention and interpretation modification tasks were not effective. Authors noted that this may have been due to a low sample size and a lack of engagement elements to make the tasks 'fun'. Finally, Franklin et al's (2016) combined study found that two of the three studies showed that therapeutic evaluative conditioning impacted its intended treatment targets and that

greater change in these targets was associated with greater reductions in self-injurious thoughts and behaviours.

Five of the studies showed that no changes to automatic processing were achieved (26, 27, 34,71, 76). Boendermaker et al. (2016) attributed these findings to small attentional biases at baseline, low numbers of training trials as compared to other trials in the areas effecting dose response relationship and having a web-based intervention which may have impacted on participants' motivation by making them take the training less seriously. Fleming et al. (2017) attributed the null findings to having biased unrepresentative sample populations and the online nature of the intervention being available only via a PC or laptop limiting those that had an infinity for mobile use. Enock et al. (2014) highlighted that high dropout rates between conditions which may have resulted from a lack of tolerability of training may have contributed to the negative results found. De Voogd et al. (2016) inferred that the negative findings may have been due to participant drop-out as most adolescents did not complete all eight intended training sessions and all assessments, which may have caused issues with implementation. Elfeddali et al. (2016), Boendermaker et al. (2016) and De Voogd et al. (2016) also highlighted that motivation for online training appeared low, which they partly attributed to the repetitive nature of the training tasks and the online nature of the training tasks, which were completed at home and resulted in lack of supervision or standardization of training circumstances.

2.6 DISCUSSION

This scoping review aimed to further investigate automatic processing tasks designed for health interventions in real-world settings amongst adults by exploring the current evidence-base around types of training tasks commonly used to target automatic processes, efficacy of these tasks, modes of delivery and impacts of gamification on tasks. A small but developing evidence base was found. Of the 14 studies reviewed, just under half of the interventions resulted in positive changes to automatic processes. The positive trials provide some evidence that this approach may be possible in the real-world, though many trials produced mixed results and issues with compliance and engagement were commonly described.

2.6.1 Types of training tasks

The review identified two main types of tasks commonly used in the field to change people's automatic processing; attentional bias modification and cognitive bias modification tasks. These tasks can be delivered via a variety of methods but the most popular in the health domain are dot-probe, visual probe and visual search tasks. The dot-probe task was first developed in 1981 (80). The task was designed to assess selective attention, specifically attentional biases to threatening auditory information, when threatening and non-threatening information were presented simultaneously to both ears in a dichotic listening task. This was later developed by in 1986 into a visual-probe tasks with the same precipice but instead of auditory information being provided visual stimuli was (31). The visual search task was is a perceptual task requiring attention, typically it involves an active scan of the visual environment for a particular object or feature (the target) among other objects or features (the distractors) (81). All

three tasks have been extensively used in the literature, with other reviews also identifying the prominence of these tasks in automatic processing interventions (33, 56, 82). These tasks have historically been used in a lab-based setting, particularly in mental health interventions seeking to change anxiety and depression. The review revealed an expansion in the field, both into a real-world setting and into other health fields such as problem drinking, smoking and suicide.

2.6.2 Usability

The field has been keeping up with digital advancements; and within the last few years there has been a shift towards the use of smartphone apps for delivery of automatic processing interventions. All automatic processing tasks contained within the review were deployed online, which made them easily accessible for use in the real-world. They were most commonly delivered via a computer or laptop, with over half of studies using this as the mode of delivery. This aligns with other reviews in the field such as Zhang et al.'s (2018) recent review into attention and cognitive bias modification apps, which found 24 cognitive bias modification apps that were commercially available. Although app usage is increasing, Zhang et al. (2018) found that most apps were not rigorously evaluated, with only eight studies being scientifically evaluated, while the other 17 were all commercial apps, of which only one was evaluated in published literature. This review has been able to add to the work by Zhang et al. (2018) finding that a further five smartphone based cognitive bias modification tasks studies have been scientifically evaluated.

Digital advancements in the field are increasingly opening pathways to make the delivery of automatic processing interventions accessible for participants and also more

manageable for researchers, and is thereby facilitating a pathway into real-world investigations of this nature. However, whilst digital platforms do increase participant accessibility in real-world environments, it is important to highlight that they do come with their limitations.

Three studies noted that the online nature of tasks and the lack of supervision and standardisation from external distractors and influences may have negatively impacted on study results (26, 34, 71). Weirs et al. (2015) highlighted that this may have been due to large drop-out rates commonly seen in online experiments and suggested making interventions more engaging to combat this. Boendermaker et al. (2016)(34) and Elfeddali et al. (2016) suggested that allowing participants to do the training part of the intervention at home may have effected their motivation levels by them taking the task less seriously. De Voogd et al. (2016) highlighted that mixed results of that study may have been due to the lack of 'stress' imposed by the laboratory environment, where traditionally most studies in this area have been conducted. Indeed, the stress of laboratory environments may in fact be beneficial to study outcomes as participants may have taken the training task less seriously in their home environment, thereby negatively affecting conditioning effects. A recent meta-analysis on web-based CBM which found that web-based studies showed smaller effect sizes than laboratory-based studies (83).

2.6.3 Effectiveness

Similarly, to other reviews in the area (54, 67) the current review also found mixed findings on the effectiveness of automatic processing tasks in real-world conditions. Six

of the included studies reported a positive finding, three of the studies found mixed results and five of the studies showed no changes to automatic processes.

Mixed results on efficacy were found for smoking, social anxiety and self-injurious thoughts and behaviours. This may have been due to participant attrition affecting overall results, and Franklin et al. (2016) suggested that mixed findings in that study may have been due to issues with a lack of engagement elements (78). This is a common criticism of bias modification tasks as they are often reported to be quite boring and repetitive by participants. There has been development in the field to make these tasks more engaging by adding in elements of gamification which uses visuals, sound effects, point systems and rewards to make the tasks more engaging(12, 13, 32-35).

Although gamification is a relatively new field, it is gaining traction fast and is being increasing used and adopted into health interventions (12, 33, 44, 45). Indeed, three of the studies highlighted gamification as potential way to increase engagement and enjoyment (26, 35, 71). However, only three of the included studies incorporated elements of gamification to enhance engagement of their interventions (34, 69, 78). Boendermaker et al. (2016) gamified an existing automatic processing task which aimed to train attention away from pictures of alcoholic beverages via a visual probe task (34). He found that the gamified automatic processing task did not improve participants' motivation to train as compared to the usual non-gamified task. In fact, some aspects of motivation appeared to deteriorate rather than improve, suggesting that gamification could have drawbacks if not done optimally.

These results, contrast to an earlier study by Boendermaker et al. (2015), where he similarly gamified an existing automatic processing task aimed at increasing user experience and motivation to use the application, and assessed the effectiveness of the task to change alcohol-related memory bias and cause behaviour change. The results of the study indicated that the gamifying automatic processing tasks could increase fun and motivation to train using the task. However, in terms of the primary outcomes, it was found that the gamified tasks did not influence bias score or drinking behaviour. This may have been due to a number of reasons including: gamification in this context changing the conditioning effects of the tasks by increasing distraction or reducing quality of stimuli or due to the use of ineffective gamification elements. The other two studies included in the review by Crane et al. (2018) and Franklin et al. (2016) saw positive effects of study outcomes with the use of games and gamified elements in their interventions. However, the effect that gamification had on influencing these outcomes was not investigated. Other reviews have also found mixed findings with the use of gamification and highlighted that attention need to be given to what gamification elements are added and when they are used (33, 35, 46, 84).

Of the effective interventions, over half of the studies targeted alcohol abuse. Successful characteristics of these interventions included use of evaluative conditioning or cognitive bias modification tasks for intervention delivery, use of personal computers for mode of delivery and use of dual-process theory.

2.6.4 Strengths and limitations

There were a number of strengths and limitations to this scoping review. To our knowledge, this was the first study in the field to synthesise a review of automatic

processing tasks that specifically focuses on real-world settings and adults. The expansive search, included both database and grey literature searching, has been able to aggregate key findings in the field in relation to significant gaps in the field including around implementation, efficacy and intervention delivery in real-world settings from broad perspectives.

However, there were limitations to the study. The studies eligibility criteria may have limited important findings from key studies in the area that did not meet eligibility requirements. For example, there are many papers in the field that focus on evaluating automatic processing tasks in real-world settings amongst children which collectively may hold key insights into the field at large (32, 52, 85). These were not included due to the adult focus of this paper. Additionally, as is practice with scoping reviews and following best-practice recommendations of conducting scoping reviews from Colquohon et al. (2014) and Arksey and O'Malley et al. (2005), included studies were not assessed for quality in relations to areas of bias such as randomisation, participant blinding and assessor blinding (86, 87). Scoping reviews are much more interested in obtaining the breadth of information available rather than assessing for quality. The disadvantage to this is that this then makes it difficult for readers to gain an insight into robustness and generalisability of findings. However, the benefit to this method is that it allows the mapping of a wider range of available resources painting an overall picture of the field at large as the guidelines for inclusion are not as stringent as a systematic review. The results of a scoping review can however sometimes inform the development of a systematic review, which is better place to deliver an assessment on quality of included studies.

2.6.5 Future directions:

The increasing use of digital platforms to deliver automatic processing tasks, while increasing population reach and accessibility does have drawbacks. Whilst, levels of monitoring and standardisation are relatively achievable in lab-based environments, it is often hard to monitor compliance and ensure adherence during real-world investigations which has implications for factors such as dosage of conditioning messages. Further research needs to be conducted into how to increase compliance and adherence in real-world settings. Future studies could potentially investigate how to include features such as external tracking by researchers into online interventions to monitor progress, incorporate time-windows into online tasks making them compulsory to engage with at certain times during the day and adding in reminders in the form of push notifications and emails which send participants reminders.

Further to that, engagement of automatic processing tasks remains a prominent issue in the area due to their inherent 'boring' nature. Gamification, offers promising capabilities and future research should further investigate how and by what mechanisms it can be added into automatic processing tasks to increase enjoyment in the field. Although thus far the research into the field of gamification is mixed, it is an important enjoyment strategy and incorporation of elements such as point systems, rewards, graphics and sounds should be further investigated, as if implemented correctly, has the potential to increase enjoyment of traditionally mundane tasks.

Increasing enjoyment of automatic processing tasks will not only address the 'boredom' factor but may have flow on effects by enhancing and amplifying the conditioning

effects of the automatic processing tasks. Participants are likely to be more receptive to conditioning effects of the tasks if they are having an overall enjoyable experience, and could potentially be associating that experience and positive feelings with the conditioning effects of the tasks, which may result in amplification of conditioning effect. This is opposed to participants having an overall frustrating experience of the tasks due to factors such as boredom and then associating that negative experience with the conditioning effects of the tasks and being inadvertently conditioned oppositely to what was originally intended. There is still much unknown about the effects of gamification in automatic processing tasks, as well as what elements of gamification to use, when to use gamification and where. It is important that future research in the field investigate how gamification can be used effectively and in a manner that maintains the integrity of the automatic processing task.

Lastly, it was also noted, that although 14 interventions were found that targeted the automatic processing pathway of dual-process theory, only two actually targeted both pathways as recommended by dual-process theory to achieve maximum changes to behaviour (17, 28, 38). It was unfortunate that there were not more studies in the field that targeted both processes during their interventions, both processes alone have shown significant ability to change behaviour, combining the processes could have great possibilities and improve design and efficacy of future health interventions and could be a crucial missing link in the design and efficacy of health interventions.

2.7 CONCLUSION

This is likely the first review to synthesise the evidence for published and grey-literature on automatic processing tasks set in real-world settings targeting adults.

Existing health interventions mainly aim to change behaviour through targeting the reflective processing pathway. However, the automatic processing pathway is an underrated and vitally important pathway that can strongly influence behaviour change. Targeting the automatic processing pathway could be a vital missing link to the successful implementation of health interventions. This review has highlighted promising research that has been able to effectively use automatic processing tasks in a real-world setting to influence behaviour change. Once only used in the mental health field in laboratory settings, automatic processing tasks are being increasingly adopted into other health fields and continuously being improve upon to increase engagement and efficacy by using online mediums and drawing from the emerging field of gamification.

Appendix 1: Data extraction template

A systematic scoping review of evidence regarding automatic processing computerised tasks designed for health interventions in real-world settings amongst Adults.

Data Extraction Form

Reviewers Name:

Date of form completion:

Journal and ranking:

References to this Trial

Check other references identified in searches. If there are further references to this trial (i.e. multiple publications for the same study) link the papers now & list below.

Code each paper	References Format: [Surname] [initial], (etc). [Title of paper]. [*Journal title*]. [Year of publication]; [volume] [(issue)]: [page numbers]
A	
B	
C	

Methods:

	Further details
Objective: *(Aim of the study as specified in paper)*	
Design as specified in paper: *(i.e. RCT, how many arms?)*	
Did the study design match what was specified? If not, why?	
Year:	
Country:	
Study Site: *(Homes etc.)*	

Methods of Analysis: *(Logistic regression, stem-and-leaf and box plots etc)*	
Recruitment incentive: *(money, credits etc.)*	

Participants:

Eligible for study (total n-value of whole study):			
	Further details Intervention:	Control:	OR Other (usual care):
Randomised: (n-value for each arm of study randomised)			
Completed: (participant completion n-value for each arm of study)			
Age: (mean value &/or range for each arm)			
Gender: (for each arm)			
Recruitment: *(through what means flyers, website etc.)*			
Reasons for subject exclusion:			
Reasons for subject inclusion:			

Interventions:

	Further details
Setting *(lab, home etc.):*	
Duration of intervention:	

Intervention delivered by: (researchers, company) **If not stated can you deduce?*	
Details of theory behind intervention: *(Dual-process models, gamification models, cognitive bias modification models etc.)*	

Targeted intervention strategies: (provide brief description)	
☐ Cognitive bias modification	
☐ Automatic evaluations	
☐ Gamification	
☐ Engagement strategies	
☐ Other strategies (please specify)	
<u>Type of intervention:</u> (tick all those that apply and provide brief descriptions):	
☐ Web-based	
☐ App-based	
☐ Smart-phone	
☐ Other digital means (please specify)	
<u>Type of control:</u> Are any of the above interventions also in the control group? If so, describe:	
☐ Web-based	
☐ App-based	
☐ Smart-phone	
☐ Other digital means (please specify)	

Outcomes:

	Further details
List the pre specified primary outcomes and how they were measured:	
List the pre specified secondary outcomes and how they were measured:	
Follow-up:(baseline,post-int)	
Additional Notes:	

Data extraction

Topics relevant to your review for Discussion	**Reported in paper (YES / NO)**	**Details**
1 Relevant studies and/or reviews identified in reference list		
2 Automatic processing/automatic evaluations/implicit biases		
3 Population group-adults		
4 Computerised tasks/cognitive bias modification tasks		
5 Health intervention		
Effectiveness of intervention		
Reasons of effectiveness/ or why it didn't work		
Real-world setting		
Gaps in literature		
Future research		

Appendix 2: Search Strategy

PubMed

Automatic Processing AND	**Computerised Tasks AND**	**Health Interventions AND**	**Real-world AND**	**Adult AND**
"Automatic process*"[tiab] OR "Implicit biases"[tiab] OR "automatic evaluation*"[tiab] OR "association learning"[tiab] OR "association learning"[mh] "Cognition"[tiab] OR "cognitive training"[tiab] OR "cognitive bias modification"[tiab] OR "motivation training"[tiab] OR "dual process*"[tiab]	"Computerised tasks"[tiab] OR "Computerized tasks"[tiab] "App-based[tiab] OR mobile technolog*"[tiab] OR "mobile app*"[tiab] OR "mobile applications"[mh] OR "software app*"[tiab] OR "electronic app*"[tiab] OR "health information systems"[mh] OR "health information system*"[tiab] OR "telemedicine"[mh:noexp] OR "mobile health" [tiab] OR "mHealth"[tiab] OR " telehealth"[tiab] OR "eHealth"[tiab] OR "computers/utilization"[mh] OR "serious games"[tiab] or "computer games"[tiab]	"Health Intervention*"[tiab] OR "health program*"[tiab] OR "preventative health"[tiab] OR "preventive health"[tiab] or "intervention*[tiab]	"Real world"[tiab] OR "Natural world"[tiab] OR "randomised controlled"[tiab} OR "non-randomised controlled"[tiab] OR "randomized controlled"[tiab} OR "non-randomized controlled"[tiab]	Adult[mh] OR "Older people"[tiab] OR "middle aged"[tiab] OR "young adult"[tiab] OR elderly[tiab]

Scopus

Automatic Processing AND	**Computerised Tasks AND**	**Health Interventions AND**	**Real-world AND**	**Adult AND**
{Automatic processing} OR {automatic processes} OR {Implicit biases} OR {implicit bias} OR {automatic evaluations} OR {automatic evaluation} OR {association learning} OR {Cognition} OR {cognitive training} OR {cognitive bias modification} OR {motivation training} OR {dual process} OR {dual processing} OR {dual processes}	{Computerized tasks} OR {Computerized tasks} OR {App-based} OR {mobile technology} OR {mobile app} OR {mobile applications} OR {mobile application} OR {software app} OR {software application} OR {electronic application} OR {electronic app} OR {health information systems} OR {health information system} OR {telemedicine} OR {mobile health} OR {mHealth} OR { telehealth} OR {eHealth} OR {computers/utilization} OR {serious games} OR {computer games}	{Health Intervention} OR {health interventions} OR {health program} OR {health programs} OR {preventative health} OR {preventive health} OR {intervention}OR {interventions}	{Real world} OR {Natural world} OR {randomised controlled} OR {non-randomised controlled}OR {randomized controlled} OR {non-randomized controlled}	Adult OR {Older people} OR {middle aged} OR {young adult} OR {elderly}

Psychinfo

Automatic Processing AND	**Computerised Tasks AND**	**Health Interventions AND**	**Real-world AND**	**Adult AND**
Automatic process*.ti,ab OR Implicit biases*.ti,ab OR automatic evaluation*.ti,ab OR association learning.ti,ab OR Cognition.ti,ab OR cognitive training.ti,ab OR cognitive bias modification.ti,ab OR motivation training.ti,ab OR dual process*.ti,ab	Computeri#ed tasks.ti,ab OR App-based.ti,ab OR mobile technolog*.ti,ab OR mobile app*.ti,ab OR OR software app*.ti,ab OR electronic app*.ti,ab OR health information system*.ti,ab OR telemedicine.ti,ab OR mobile health .ti,ab OR mHealth.ti,ab OR telehealth.ti,ab OR eHealth.ti,ab OR computers/utili#ation*.ti,ab OR serious game*.ti,ab or computer game*.ti,ab	Health Intervention*.ti,ab OR health program*.ti,ab OR preventative health.ti,ab OR preventive health.ti,ab or intervention*.ti,ab	Real world.ti,ab OR Natural world.ti,ab OR randomi#ed controlled.ti,ab OR non-randomi#ed controlled.ti,ab	Adult*.ti,ab OR Older people.ti,ab OR middle aged.ti,ab OR young adult*.ti,ab OR elderly.ti,ab

Embase

Automatic Processing AND	**Computerised Tasks AND**	**Health Interventions AND**	**Real-world AND**	**Adult AND**
automatic process* OR Implicit biases* OR automatic evaluation* OR association learning OR Cognition OR cognitive training OR cognitive bias modification OR motivation training OR dual process*	computerised task* OR app-based OR mobile technolog* OR mobile app* OR software app* OR electronic app* OR health information system* OR telemedicine OR mobile health OR mHealth OR telehealth OR eHealth OR computers OR serious game* OR computer game*	health Intervention* OR health program* OR preventative health OR preventive health or intervention*	real world OR Natural world OR randomised controlled OR non-randomised controlled	adult* OR Older people OR middle aged OR young adult* OR elderly

CINAHL:

Automatic Processing AND	**Computerised Tasks AND**	**Health Interventions AND**	**Real-world AND**	**Adult AND**
Automatic process* OR Implicit biases* OR automatic evaluation* OR association learning OR cognition OR cognitive training OR cognitive bias modification OR motivation training OR dual process*	Computeri?ed task* OR app-based OR mobile technolog* OR 'mobile app* OR software app* OR electronic app* OR health information system* OR telemedicine OR mobile health OR mHealth OR telehealth OR eHealth OR computers/utili?ation* OR serious game* or computer game*	Health Intervention* OR health program* OR preventative health OR preventive health or intervention*	Real world OR Natural world OR randomi?ed controlled OR non-randomi?ed controlled	Adult* OR Older people OR middle aged OR young adult* OR elderly

Cochrane:

Automatic Processing AND	**Computerised Tasks AND**	**Health Interventions AND**	**Real-world AND**	**Adult AND**
"Automatic process" OR "Implicit biases" OR "automatic evaluation" OR "association learning" OR Cognition OR "cognitive training" OR "cognitive bias modification" OR "motivation training" OR "dual process"	"Computerised task" OR "app-based" OR "mobile technology" OR "mobile app" OR "software app" OR "electronic app" OR "health information system" OR telemedicine OR "mobile health" OR mHealth OR telehealth OR eHealth OR computers OR "serious game" or "computer game"	"Health Intervention" OR "health program" OR "preventative health" OR "preventive health" or intervention	"Real world" OR "Natural world" OR "randomised controlled" OR "non-randomised controlled"	Adult OR "Older people" OR "middle aged" OR "young adult" OR elderly

Appendix 3: Automatic processing targeted health outcomes and effectiveness

Reference	Condition targeted	Description of intervention	Measure	Main outcomes reported
Robinson 2017(72)	Smoking	Attentional re-training-visual probe task	Attentional re-training-visual probe task	To investigate the effect of attentional retraining (AR) on attentional bias and smoking in African American smokers. AR administered on a mobile device reduced attentional bias in African American smokers and had mixed effects on smoking.
Clarke 2015(74)	Insomnia	Attentional bias modification-attentional probe task	Attentional bias modification-attentional probe task and behavioural measure	To assess whether targeted delivery of an ABM task during the pre-sleep period could reduce symptoms of insomnia and the cognitive symptoms of pre-sleep arousal. These results suggest that attentional bias modification targeting vigilance for sleep-related threat during the pre-sleep period has the capacity to reduce cognitive arousal and improve insomnia symptoms.
Yang 2017(73)	Social anxiety	Cognitive bias modification-attention bias modification (dot probe tasks) and interpretation bias	Dot-probe test word sentence association paradigm	To compare the effectiveness of three different types of training programmes (cognitive bias modification-attention, CBM-A; cognitive bias modification-interpretation, CBM-I; attention and interpretation modification, AIM) administered via smart-phones by using a control condition (CC). The study supports the feasibility of delivering CBM-I via smartphones, but the effectiveness of CBM-A and AIM training via smartphones was limited.

Reference	Condition targeted	Description of intervention	Measure	Main outcomes reported
Fleming 2017(76)	Self-esteem and negative attitudes that gay men may have towards homosexuality.	Evaluative conditioning task	Self-esteem implicit association test and sexual orientation implicit association test	To determine if evaluative conditioning deployed over the Internet could modify self-esteem and negative attitudes that gay men may have towards homosexuality. Internet-based EC did not produce significant effects in implicit or explicit self-directed attitudes.
Deursen 2015(77)	Alcohol abuse	Cognitive bias modification-consisting of three tasks: attentional bias retraining, alcohol/no-go training, and approach bias retraining.	Implicit association test	It was expected that executive functions (working memory, response inhibition) would moderate the relationship between automatic associations and alcohol use and that this effect would be stronger in individuals with strong motivation to change. Results provide partial support for the moderating role of motivation in the interplay between automatic processes and executive functions.

Reference	Condition targeted	Description of intervention	Measure	Main outcomes reported
De Voogd 2016(26)	Anxiety and depression	Attentional bias modification-Visual search attention training	Dot-probe and visual search based attentional training	To investigate the efficacy of multiple sessions of online attentional bias modification training to reduce attentional bias and symptoms of anxiety and depression, and to increase emotional resilience in youth. The study provided no support for the efficacy of online attentional bias modification training as a preventive intervention to reduce symptoms of anxiety or depression or to increase emotional resilience in youth.
Enock 2014(27)	Social anxiety	Attention bias modification-dot-probe training	Attention bias modification-dot-probe training	To test the efficacy of smart phone delivered CBM-A. No statistical significance between the two groups in reducing social anxiety was found.
Monk 2017(70)	Alcohol abuse	Evaluative conditioning- stop signal task	stop signal task-visual stimuli	The current study examined the hitherto untested assertion that the disinhibiting effects of alcohol-related stimuli might generalise to other appetitive liquid stimuli, but not to non-appetitive liquid stimuli. These findings suggest that decreases in inhibitory control in response to alcohol-related cues might generalise to other appetitive liquids, possibly due to evaluative conditioning.

Reference	Condition targeted	Description of intervention	Measure	Main outcomes reported
Weirs 2015(35)	Alcohol abuse	Cognitive bias modification: attention control and approach bias re-training	Alcohol Attention Control Training Program- pictorial alcohol-Stroop tasks	Investigate whether different varieties of CBM (attention control training and approach-bias re-training) could be delivered successfully in a fully automated web-based way and whether these interventions would help self-selected problem drinkers to reduce their drinking. The general pattern of findings was that participants in all conditions reduced their drinking.
Boendermaker 2016(34)	Alcohol abuse	Gamified attentional bias modification- visual probe tasks	Assessment version of the VPT and another task that also measures attentional bias but is procedurally different, that is, the visual search task (VST)	To prevent escalation of regular alcohol use into problematic use in university students through the use of a gamified cognitive bias modification game. The novel game-like approach proved insufficient to motivate young adults to train, in comparison with a regular CBM-A training. In fact, some aspects of motivation appeared to deteriorate rather than improve, suggesting that gamification can have drawbacks if not done optimally.

Reference	Condition targeted	Description of intervention	Measure	Main outcomes reported
Crane 2018(69)	Alcohol abuse	Cognitive bias re-training	Not stated	To evaluate intervention components of an alcohol reduction app: Drink Less. The combination of enhanced Normative Feedback and Cognitive Bias Retraining and enhanced Self-monitoring and Feedback and Action Planning yielded improvements in alcohol-related outcomes after 4-weeks.
Elfeddali 2016(71)	Smoking	Attentional bias modification-visual probe tasks	Visual probe task	To assess the efficacy of a multiple-sessions Web-based Attentional Bias Modification (ABM) self-help intervention in smokers who made a quit-attempt. Web-based ABM training is ineffective in fostering cognitive bias reduction and continued smoking abstinence.
Franklin 2016(78)	Self-injurious thoughts and behaviours (suicide).	Therapeutic evaluative conditioning-game-like app	Affect misattribution procedure	The goal of this series of studies was to take initial steps toward developing an effective self-injurious thoughts and behaviours treatment that could easily be delivered on a very large scale. Two of the 3 studies showed that therapeutic evaluative conditioning impacted its intended treatment targets and that greater change in these targets was associated with greater self-injurious thoughts and behaviours reductions.
McNulty 2017(75)	Relationship satisfaction.	Evaluative conditioning	Evaluative-priming task	Examined whether directly altering affective associations involving a relationship partner through evaluative conditioning could lead to changes in relationship satisfaction. These results provide novel evidence for a mechanism of change in relationship satisfaction.

CHAPTER 3

Enjoyment as a moderator on automatic processes towards exercise in gamified 'Flex' App in a Randomised Controlled Study

Statement of Authorship

Title of Paper	**Enjoyment as a moderator on automatic processes towards exercise in gamified 'Flex' App in a Randomised Controlled Study**
Publication Status	☐ Published ☐ Accepted for Publication ☐ Submitted for Publication ☑ Unpublished and Unsubmitted w ork w ritten in manuscript style
Publication Details	Jayasinghe H, Short C.E, Hume C, Rasera M, Braunack-Mayer A, Rebar A.L et al..

Principal Author

Name of Principal Author (Candidate)	**Harshani Jayasinghe**		
Contribution to the Paper	Aided with the development of website, assisted with ethics, created and managed recruitment advertisements, analysed data, wrote manuscript and edited manuscript.		
Overall percentage (%)	85%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	14 May 2019

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

Name of Co-Author	**Camille E. Short**		
Contribution to the Paper	Supervised development of work assisted in data analysis and interpretation and helped evaluate and edit the manuscript.		
Signature		Date	14 May 2019

Name of Co-Author	**Clare Hume**		
Contribution to the Paper	Supervised development of work helped in interpretation of data and helped evaluate and edit the manuscript.		
Signature		Date	16 May 2019

Name of Co-Author	**Magne Rasera**		
Contribution to the Paper	Developed website for participants, developed data repository and assisted with ethics.		
Signature		Date	15 May 2019

Name of Co-Author	Annette Braunack-Mayer		
Contribution to the Paper	Provided feedback on qualitative elements of study and assisted in editing of manuscript.		
Signature		Date	15 May 2019

Name of Co-Author	Amanda L. Rebar		
Contribution to the Paper	Conceptualisation to origins of work, supervision of work, completed ethics and data analysis.		
Signature		Date	14 May 2019

3.1 CONTEXT OF THIS RESEARCH

The chapter describes the second original research arising from this Masters thesis. The first study highlighted the existing evidence base for the use of computerised automatic processing tasks in real-world settings among adults. Study 2, was nested among a randomised controlled trial run out in a real-world setting. The study evaluated an app called 'Flex', which aimed to target physical activity among Australian adults.

The randomised controlled study was conducted in conjunction with Dr Amanda Rebar and her team at the Centre for Physical Activity Studies at Central Queensland University. The RCT aimed to evaluate changes in automatic associations directly after playing the app and at a 24-hour follow-up point among an Flex experimental and Flex control group. At the 24-hour follow-up point, a significant between-group effect was found such that people in the Flex experimental group had more favourable automatic associations of physical activity than those in control group.

The nested study within this thesis, was interested in further exploring this association, by examining if the moderator 'enjoyment' was responsible for amplifying the conditioning effect of the automatic processing task. This was completed by evaluating enjoyment directly via Fang et al.'s (2010) 'enjoyment of computer game play' questionnaire and a 12-item process evaluation survey examining user-experience.

3.2 ABSTRACT

Background:

According to dual process models, both reflective and automatic processes influence behaviour. Automatic processing is fast, immediate, non-conscious, and unintentional. Reflective processing centres around logical reasoning; it is slow, step-by-step, voluntary and intentional. Flex, is an app designed on automatic processing, evaluative conditioning and gamification principles. It is made up of four games intended to promote exercise to Australian adults by targeting automatic processing (non-conscious biases). A real-world randomised controlled study (RCT) was conducted over two days, that found use of Flex led to a positive change in participant biases towards physical activity stimuli. Having an overall enjoyable experience while playing an automatic processing task may improve upon how well conditioning stimuli are reinforced. A nested study sought to further evaluate this relationship to determine if enjoyment moderated the positive findings of the RCT.

Methods: Participants were recruited via Instagram and Facebook through online advertising. The study took 50-60 minutes to complete over two days. After consenting, participants downloaded the freely available Flex app from App stores. Upon download, participants were randomly allocated into either the Flex experimental or Flex control group, and were asked to play the games 18 times. Flex is made up of four games [Figure 1] that all have a Flex experimental and control version. Flex experimental versions of the games had 75% physical activity stimuli while control versions had none. An implicit association test (IAT) was used to test changes to automatic processes towards physical activity immediately after game play and at 24-hours follow-up. Enjoyment was measured via Fang et al.'s (2010) validated

‘enjoyment of computer game play’ questionnaire and process evaluation data was collected with a 12-item survey.

Results: After 24 hours, 254 participants had played the Flex app (n=128 in Flex control group; n=126 Flex experimental group). The Flex experimental group was 87% female (Mean age=34.0, SD: 10.8) and the Flex Control was 76% female (Mean age= 31.7. σ= 10.8). Mean IAT scores after 24 hours were 0.79 for the experimental group and 0.63 for the control group. The interaction between experimental group and enjoyment was not statistically significant (p=0.709), so there is limited evidence that enjoyment moderated the effect of the Flex experimental condition on IAT. For every 1 unit increase in enjoyment, IAT scores were expected to increase by 0.009 units (95% CI -0.000-0.019, p=0.060) and 0.012 units (95% CI 0.003-0.021, p=0.010) in the Flex experimental and Flex control groups, respectively. At the mean level of enjoyment, IAT scores were estimated to be 0.143 units higher among participants in the experimental group. The process evaluation survey found that participants enjoyed Flex because it was simple, entertaining and had high quality graphics and gameplay.

Conclusions: Although Flex has the ability to favourably change people’s automatic processing towards physical activity stimuli, enjoyment did not appear to modify the conditioning effect of automatic processing observed. However, enjoyment may still be important to consider for encouraging participant usage of Flex and other automatic processing gamified apps. The process evaluation results provide some insight into how future studies may improve upon enjoyment for health message delivery.

Key Words: Cognitive bias modification, automatic evaluations, automatic processing, implicit biases, evaluative conditioning, digital game, gamification, gamified, physical activity

3.3 INTRODUCTION

Physical inactivity is a leading cause of modifiable mortality and morbidity around the world (88, 89). According to the World Health Organization , 1 in 4 adults are not meeting the recommended guidelines for physical activity, and this contributes to the development of a number of chronic health related diseases including heart disease, diabetes, cancer, mental health problems and dementia (88, 89). Increasing uptake, participation and maintenance of physical activity is a global public health priority (89, 90). Numerous health interventions have been developed and implemented to target the issue. One promising intervention type at creating behaviour change are digital behaviour change interventions (91).

An emerging area of research in the field of digital behaviour change interventions are the use of automatic processing tasks. Dual-process theories propose that the brain uses two types of thinking to influence behaviour: automatic processing and reflective processing (17, 19). Automatic processing is fast, immediate, non-conscious, and unintentional (17). When the automatic processing pathway is stimulated, a person evaluates a stimulus in terms of its affective and conditioned properties based on their mental representation of that concept along with the network of concepts associated with it. By doing so, a stimuli can capture an individual's attention (attentional bias), elicit spontaneous evaluations of the stimulus being 'good' or 'bad' (automatic evaluations) and elicit a behavioural tendency to approach or avoid it (approach/avoidance bias). Reflective processing centres around logical reasoning; it is slow, step-by-step, voluntary and intentional (17, 19). It regulates the influence of automatic processes to guide behaviour in line with personal goals and social norms. These two processes happen simultaneously and can often compete against each other

creating conflict (9, 20). Dual-process theory highlights the importance of targeting both pathways in interventions to observe changes in behaviour (2, 17, 20, 58). However, most physical activity health interventions are designed to target the reflective system (9, 58) and self-regulatory processes (59, 82).

People only have a certain threshold for capacity to self-regulate; this is likely to be particularly true if they have strong automatic processes guiding them in the other direction. Automatic processing of physical activity as either 'good' or 'bad' will elicit a behavioural response of approach or avoidance towards physical activity(15). Some physical activity interventions have shown that approach tendencies towards physical activity override participants' intentions to be active (16, 36). The likelihood of peoples' intentions translating into behaviour change is around about 48%, focus needs to be shifted beyond targeting people's intent (15). Some physical activity interventions have shown that approach tendencies towards physical activity override participants' intentions to be active (16, 36)

Automatic processing tasks have been shown to be effective in lab-based environments of changing participants automatic process towards stimuli (28, 29,32,33, 38). Changes have been seen in the field of anxiety, depression and drinking behaviour. However, participants often complain that tasks are 'repetitive' and 'boring' (29). Previous research has indicated that participant enjoyment is a key driver of use of digital behaviour change interventions in the real-world (13, 47, 92, 93). If participants are not enjoying a task, it may lead to a lack of efficacy (41), retention (42), poor data quality and may have negative effects on study outcomes(43). Enjoyment is a complex experience, and it likely reflects the intersection of a variety of factors, including

cognitive, affective, social and physiological elements (13, 40). Hence, it is important to consider the role of enjoyment of participants when designing automatic processing interventions. One method that is being increasingly used to make automatic processing tasks and digital behaviour change interventions in general, more enjoyable is gamification(32-35).

Gamification seeks to engage participants by using gaming style elements to make tasks more fun and engaging (graphics, sounds, rewards, points and leader boards) (44). Thus far, although they have been applied to a range of digital interventions, mixed effects have been seen for their use in enhancing enjoyment, encouraging usage and influencing changes to automatic processing (32, 34, 46, 84).

One possible reason that automatic processing studies are finding mixed results could be to do with enjoyment acting as a moderator of the conditioning effect. A moderator is a variable that affects the strength of the relationship between a dependent and independent variable. While enjoyment can be important for usage, it may also influence the conditioning effect directly. That is, if a participant has an overall enjoyable experience while completing an automatic processing task designed to condition positive associations, it is possible that this experience will amplify the positive effects of the training. Conversely, the opposite could be true. If a person has an overall frustrating experience of an automatic processing task designed to condition positive associations, the conditioning effect may be weaker or even reversed due to the presence of negative emotions during conditioning. There are no studies investigating the moderating effects of enjoyment in contributing to the conditioning effects of automatic processing tasks.

Flex is a gamified automatic processing task which was implemented in a real-world setting as a randomised controlled trial to examine the efficacy. The aim of Flex was to strengthen or generate positive automatic evaluations of physical activity in an enjoyable way by using gamified evaluative conditioning tasks. The main RCT found that when compared to the control version of the app, there was a significant between-group effect observed at the 24-hour follow-up such that people who accessed the Flex experimental version of the app had more favourable automatic associations of exercise, as measured by an implicit association test (IAT), than those who accessed the control version.

This study, which is a nested study within the main RCT, hypothesised that 'enjoyment' may be acting as a moderator to the positive and significant effect seen during the main RCT study in which a positive and significant relationship was seen between IAT score and use of Flex app. As the only difference between Flex experimental and Flex control was the use of physical activity stimuli (70% PA stimuli in Flex experimental), which was replaced in the control version with similar non-physical activity stimuli, it was not expected that enjoyment would be different between the two groups. However, given the importance of enjoyment and suggestions from other researchers in the field to incorporate gamification elements into study design (26, 32-35, 69) a process evaluation survey was also conducted to provide key insights about levels of enjoyment and frustration, use of gamification and real-world suitability of Flex.

This nested study, aimed to 1) examine of enjoyment acting as a moderator and potentially amplifying the significant and positive conditioning effect observed during

the Flex RCT at the 24-hour follow-up period and 2) use a process evaluation survey to evaluate if people enjoyed ‘Flex’ and determine real-world suitability of the app.

3.4 METHODS

3.4.1 Study design

This study involves a secondary analysis of data from the Flex RCT. Ethics was obtained from the Human Ethics Research Committee of Central Queensland University (Application ID: 0000021010) and The University of Adelaide (Application ID: 33004). All participants were given adequate time to review the 'Participant Information Sheet' and 'Consent' forms before deciding if they wished to participate.

3.4.2 The Flex intervention

Flex was developed by modelling existing standard automatic processing computerised tasks (94) the research group's own research (23, 95), and in line with evidence from existing literature on automatic processing and gamification theory (13, 96). Flex has 70% physical activity stimuli and 30% neutral stimuli. The control version of the app had no physical activity stimuli but was otherwise identical. All games had multiple levels, which unlocked as the user progressed and attained enough points to progress to the next level. The secondary analysis completed in the nested study sought to evaluate the role of enjoyment asa moderator to the main finding of the RCT which was that there was a significant between-group effect observed at the 24-hour follow-up such that people who accessed the Flex experimental version of the app had more favourable automatic associations of exercise than those who accessed the control version.Enjoyment was not expected to differ between the intervention and control groups due to the only difference between the two groups being the lack of physical activity stimuli in the control group.

The four games that make up the Flex intervention, branded as brain training games, were made freely and publicly available on the Apple and Google App stores prior to the trial [Table 1].

Table 1: Characteristics of Flex games

Game	Aim	Description of Game	Automatic Processing Style
Flashback 	To find and match identical pairs of cards by flipping the cards over.	A series of cards are presented face-down. Most icons that appear in the game are related to physical activity (basketballs, footballs and flippers). Points are gained when items are correctly matched. If cards are not matched correctly, the cards automatically flip back until a correct match is made.	Approach-avoidance directly using approach training
Basket-  **case**	To catch as many physical activity stimuli as possible by moving the basket at the bottom of the screen when stimuli appear.	A wicker basket is presented on the bottom of the screen, participants need to collect as many physical activity stimuli as possible and avoid catching neutral stimuli such as teddy bears or negative stimuli such as bombs. Points are gained when the correct items are caught.	Approach-avoidance directly using approach training
Switch-up 	To get the transport icons (taxi, cycler, runner) to their destinations.	A series of roads are presented that diverge to different roads. Arrows are presented in the centre of bridging roads, changing the direction of the arrow on a road aligns to which path the icon follows. Icon colour corresponds to final destination landmark colour. Points are gained when icons are delivered correctly to their destination.	Approach-avoidance directly using approach training

Game	Aim	Description of Game	Automatic Processing Style
Scrambled 	To un-scramble the letters of a scrambled word to make a real word.	A scrambled word is presented in the middle of the screen. The word needs to be unscrambled in a set time-frame using the alphabetical letters supplied per round. As people win levels, the words get longer (up to 14 letters). Points are gained when words are correctly solved.	Approach-avoidance bias indirectly using evaluative conditioning

3.4.3 Eligibility and recruitment

To be eligible for participation in the study participants had to be over 18 years old, a resident of Australia and able to complete the two-day consecutive online assessments. The study occurred online and participants were recruited through social media advertising on Facebook, Instagram and Twitter. Advertising was conducted over 21 days from the 16th of May to the 5th of June 2018. Initially, one advertisement was released; however, after a few days of recruiting it became evident that only a small minority of male participants were signing up for the study. As such, a second advertisement was released with similar content but targeted specifically towards males in hopes of increasing recruitment numbers.

3.4.4 Procedure

Participation in the study took 50 to 60 min over two days. Participants were guided to the study website by a link on the study advertisements. The study website provided information on the study and eligibility criteria. If participants wanted to proceed to take part in the study, they were given the opportunity to provide informed consent via

the website by signing an online consent form and then were prompted to create a personalised account through the website. Participants were then immediately emailed an automated email that highlighted how to download ‘Flex’ and were instructed to play the Flex games 18 times (based on average gameplay using App store data). Participants were randomised into Flex experimental or control group upon download via a computer-generated code in-build into the app during development. Participants were instructed via email that they could either play multiple levels in a single game or in any combination of the four available choices. Measurements for IAT and enjoyment were conducted immediately after game play ≤2 hours and IAT was measured again at 24-hours follow-up. Condition allocation was blinded for participants and the research team until analyses were completed. Only the results of the 24-hour follow-up period is contained within this paper, as that is where the significant differences between the two groups was observed. Participant flow of the study is demonstrated in Figure 1.

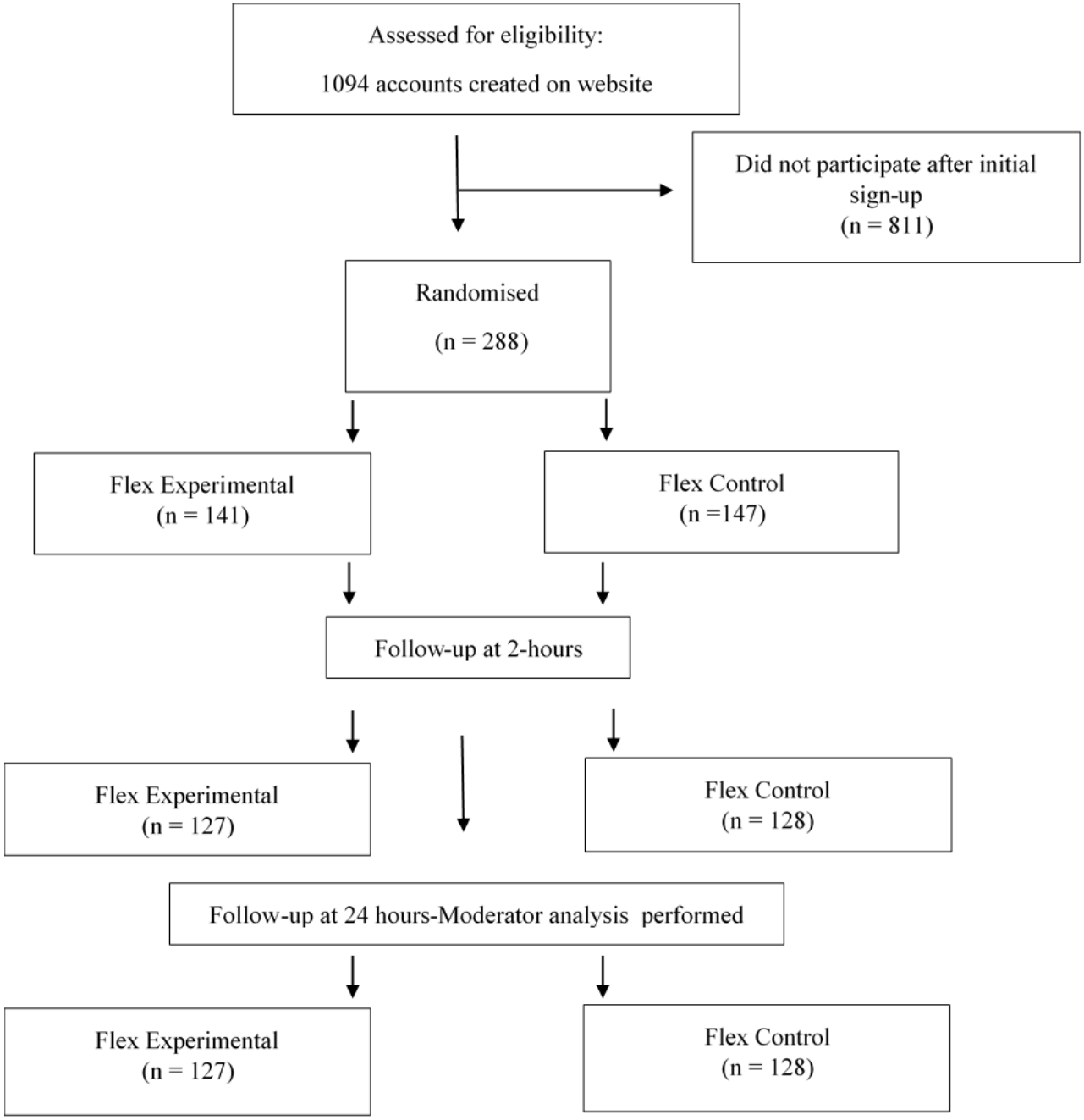


Figure 1: Flow diagram of study

3.4.5 Measures

Automatic Evaluations of Physical Activity

The impact of the flex app on automatic evaluations of physical activity was assessed using an Implicit Association Test (IAT) at the immediate and 24-hour follow-up. The IAT determines strength of automatic evaluations based on the time it takes people to respond to trials within a computer-based task. Established research within automatic processing research around physical activity had used a measure called implicit association test (IAT) to measure automatic associations of physical activity relative to sedentary behaviour. Hence, this study also chose to use an IAT to measure automatic processing.

The IAT was performed on the web-based Inquisit 5 software (Millisecond), which was free and simple for participants to access on personal computers. It took approximately five minutes to complete and consisted of seven blocks. These blocks were made up of worded stimuli targeting the concepts of physical activity vs sedentary behaviour and the attributes pleasant vs unpleasant. Three studies provided the basis of the stimuli included in the IAT. Rebar et al. (2016) study provided input into Flex experimental stimuli used, Chevance et al. (2017) provided input into sedentary stimuli used, and Conroy et al. (2010) provided the basis for the pleasant and unpleasant stimuli used.

The IAT produces a standardized score based on the Cohen's d effect size equation. The interpretation was such that '0' meant there was no relative evaluative preference toward physical activity as opposed to sedentary behaviour. Positive scores indicated more favourable automatic evaluations toward activity, with higher being more

favourable. Negative scores indicated comparatively more favourable automatic evaluations toward sedentary behaviour, with more negative scores being more favourable toward sedentary behaviour.

Enjoyment

Nabi and Krcmar's (2004) seminal study in the field of media enjoyment first introduced the concept of the tripartite model of media enjoyment. This model conceptualized enjoyment as an attitude with affective, cognitive, and behavioural components that exert mutual influences on one another. Following from this, Fang et al. (2010) developed and validated an 11-item tool based on this model to evaluate player enjoyment of computer games (Appendix 1).

Enjoyment related to using the app was assessed at the first follow-up point, immediately after app (≤2 hours) use with the Fang measure (97). Total enjoyment scores were calculated for each participant by summing the responses for the 11-items of the Fang instrument (97). The questionnaire was split up into three domains: Affect (5 questions), Behaviour (3 questions) and Cognition (3 questions). For each question, participants were given the opportunity to choose from a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree). Possible scores for overall enjoyment of the combined scale ranged from 11 to 77. For the subscales, scores could range from 5 to 35 points for affect and for behaviour and cognition scores could range from 3 to 21 points. Negatively worded items were reverse coded for the constructs of affect and behaviour as the questions in these constructs had a negative connotation, so to ensure that higher scores on the scale equalled better engagement these constructs were reverse coded. Enjoyment was then summed for all constructs and all participants (n=254)

using data from the first time-point of 2-hours follow-up. An internal reliability analysis of Cronbach's Alpha was also completed on the Fang measure (97) using Stata. Internal reliability analysis of the questionnaire via Stata revealed that the overall Cronbach's Alpha was 0.71 for the entire questionnaire, with each of the sub-scales being ≥0.70 (Affect: 0.75, Behaviour: 0.77 and Cognition: 0.74).

Total Enjoyment scores were calculated for each subject by summing the responses for the 11-items of the instrument developed by Fang et al (2010). Each item was answered on a 7-point Likert-type scale. Possible enjoyment scores thus range from 11 to 77.

The 11-items of the Fang et al Enjoyment instrument comprise three subscales measuring Affect, Behaviour and Cognition. Scores for each subscale were calculated by summing responses from the relevant items for each subscale. Possible scores for the Affect subscale range from 5 to 35, while possible scores for Behaviour and Cognition range from 3 to 21.

3.4.6 Process evaluation

Participants also completed a short purpose-built process evaluation survey evaluating user experience and recommendations for improving the app [Table 2]. The survey was made up of two constructs: user-evaluation (open-ended questions) and real-world efficacy (3-6 point likert-scale and open-ended questions) (Appendix 2). Participant characteristics including age, gender, and self-efficacy levels of using technology were also collected at the beginning of the study and evaluated using STATA.

3.4.7 Statistical analysis

Sample size: An a priori sample size calculation was conducted to determine the sample size needed for the main RCT analysis. A total sample size of N=216 (n=108 per group) was required to detect a difference in automatic evaluation between treatment groups of effect size d=0.34 with 80% power at the 5% significance level. The effect size was determined as the mid-point between meta-analytic findings of lab-based evaluative conditioning effects (Hofmann et al.., 2010) and real-world correlational studies of automatic evaluations and Flex experimental behaviour (Chevance et al.., 2018) and was considered to be a clinically meaningful change in automatic evaluation. A sample size calculation was not conducted a priori for the nested study which was a secondary analysis.

Moderation analysis: The moderation analysis was performed using STATA version 15.0 (StataCorp, Texas) on complete cases at 24 hour follow-up (n=254). Descriptive statistics were calculated for all study variables. Differences in enjoyment between Flex experimental and Flex control were assessed by inspection of mean and standard deviation scores of the enjoyment questionnaire using STATA. Enjoyment was entered as a predictor for all participants that had 24-hour IAT data. Linear regression was used to examine the effect of the experimental condition on IAT scores, with an interaction term between treatment and enjoyment included to assess whether this effect was moderated by level of enjoyment. Mean differences in IAT scores between treatment groups for enjoyment scores ranging from 15 to 70 were estimated post-hoc. Graphical inspection of the residuals indicated that the model fit the data adequately. The level of statistical significant was set to 0.05.

Differences in IAT scores between intervention and control groups, to examine how IAT varies across the range of total enjoyment scores was analysed using the "margins" command in Stata. A "margin" is a statistic computed from predictions from a model while manipulating the values of the covariates. In this case, the command allowed the mapping of the values of enjoyment using the model from the linear regression. The observed enjoyment scores in the sample ranged from 17 to 68. Estimated differences using the model in IAT score between Flex experimental and Flex control for enjoyment scores ranging from 15 to 70, in increments of 5 units were then mapped.

Process evaluation survey : Data was collected via the online database and then exported into excel. For questions of a quantitative nature, frequencies, means and standard deviations were calculated. For the qualitative open-ended questions of the survey, a coding key was developed based on common themes observed in participant's responses. Themes were then revised and eventually reduced to main themes. These themes were then made into quantitative form by assigning a numerical value to each of the themes, and collating them as a total number of occurrences and converting this into a percentage. This technqiue is called 'qualitative content analysis' which seek to preserve the advantages of quantitative content analysis for qualitative text interpretations(98).

3.5 RESULTS

3.5.1 Descriptive analyses

Flow of participants in the study and participant characteristics

After 24 hours, 254 participants had played the Flex app (n=128 in Flex control group; n=126 Flex experimental group). The Flex experimental group was 87% female (Mean age=34.0, SD: 10.8) and the Flex Control was 76% female (Mean age= 31.7. σ= 10.8). Mean IAT scores after 24 hours were 0.79 for the experimental group and 0.63 for the control group. Both groups had the same confidence levels for downloading and using apps (Table 2). The interaction between experimental group and enjoyment was not statistically significant (p=0.709), so there is limited evidence that enjoyment moderated the effect of the Flex experimental condition on IAT. For every 1 unit increase in enjoyment, IAT scores were expected to increase by 0.009 units (95% CI -0.000-0.019, p=0.060) and 0.012 units (95% CI 0.003-0.021, p=0.010) in the Flex experimental and Flex control groups, respectively. At the mean level of enjoyment, IAT scores were estimated to be 0.143 units higher among participants in the experimental group. The process evaluation survey found that participants enjoyed Flex because it was simple, entertaining and had high quality graphics and gameplay.

Table 2: Characteristics of Flex participants at 24-hour follow-up period (n=254)

Demographic characteristics	All	Flex Experimental (n=126)	Flex Control (n= 128)
Female gender (n,% women)	204(82%)	109 (87%)	95(76%)
Age (years) (Mean ± SD)	32.9±10.8	34.1 ±10.7	31.7±10.8
IAT Score at 24-hour follow up (Mean ± SD)	0.71 ±0.46	0.79 ± 0.41	0.63± 0.49
Confidence at downloading apps (1[not confident]-> 7[very confident])	7	7	7
Confidence at using apps (1[not confident]-> 7[very confident])	7	7	7
Confidence at daily use of apps (1[not confident]-> 7[very confident])	6	6	6

3.5.2 Enjoyment of computer game questionnaire

Table 3 shows the total enjoyment scores across all three sub-scales of all participants (n=254) in the intervention as well as the results for enjoyment across Flex experimental (n=126) and Flex control groups (n=128). The average enjoyment score

for combined group results was μ=50.55 σ= 8.22. Mean enjoyment scores between the two groups was fairly similar with Flex experimental (μ=51.18 SD: 8.05) and Flex control (μ=50.10 SD: 8.70) (Table 2).

Table 3: Sub-scale enjoyment results of Flex Experimental and Flex Control

	All	**Flex experimental**	**Flex Control**
Number (n)	254	126	128
Total Enjoyment			
Mean (μ)	50.55	51.18	50.10
Standard Deviation (σ)	8.22	8.05	8.70
Min	23	23	23
Max	70	70	69
Affect			
Mean (μ)	27.9	28.1	27.7
Standard Deviation (σ)	4.84	4.94	4.75
Min	7	7	12
Max	35	35	35
Behaviour			
Mean (μ)	15.9	15.7	16.1
Standard Deviation (σ)	4.61	4.74	4.49
Min	3	3	3
Max	21	21	21
Cognition			
Mean (μ)	14.6	15.0	14.2
Standard Deviation (σ)	3.32	3.04	3.54
Min	3	6	3
Max	21	21	21

3.5.3 Enjoyment as a moderator of the effect of Flex experimental condition on IAT score

In both treatment groups, IAT scores increased as level of enjoyment increased, but there was limited evidence to suggest that the effect of enjoyment on IAT differed between groups (p=0.709 for the interaction). The effect of an increase in enjoyment on IAT score were similar for experimental and control groups. Specifically, every 1 unit increase in enjoyment from the mean level of enjoyment was associated with an increase in IAT of 0.012 for the Flex experimental group (95% CI 0.003, 0.021; p=0.010) and 0.009 in the control group (95% CI -0.000, 0.019; p=0.060).

In addition, at the mean level of observed enjoyment (μ=51), IAT scores for participants in the Flex PA group were on average 0.143 units higher than that for participants in the control group (95% CI 0.033, 0.254; p=0.01). Marginal mean IATs for each level of enjoyment was also mapped for comparison (Figure 2). Estimated differences in IAT scores between groups were statistically significant for enjoyment levels in the range of 45-55. Differences in IAT between groups decreased as enjoyment scores increased (Figure 3).

Figure 2: Marginal mean IAT score for each level of enjoyment for Flex groups

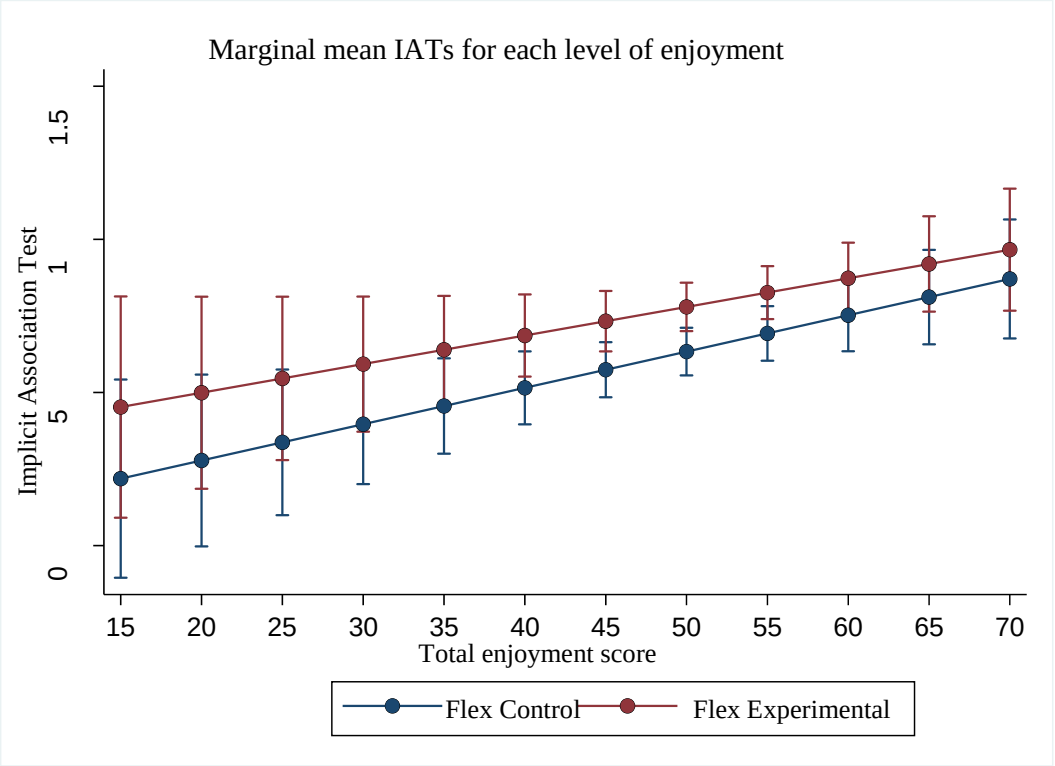
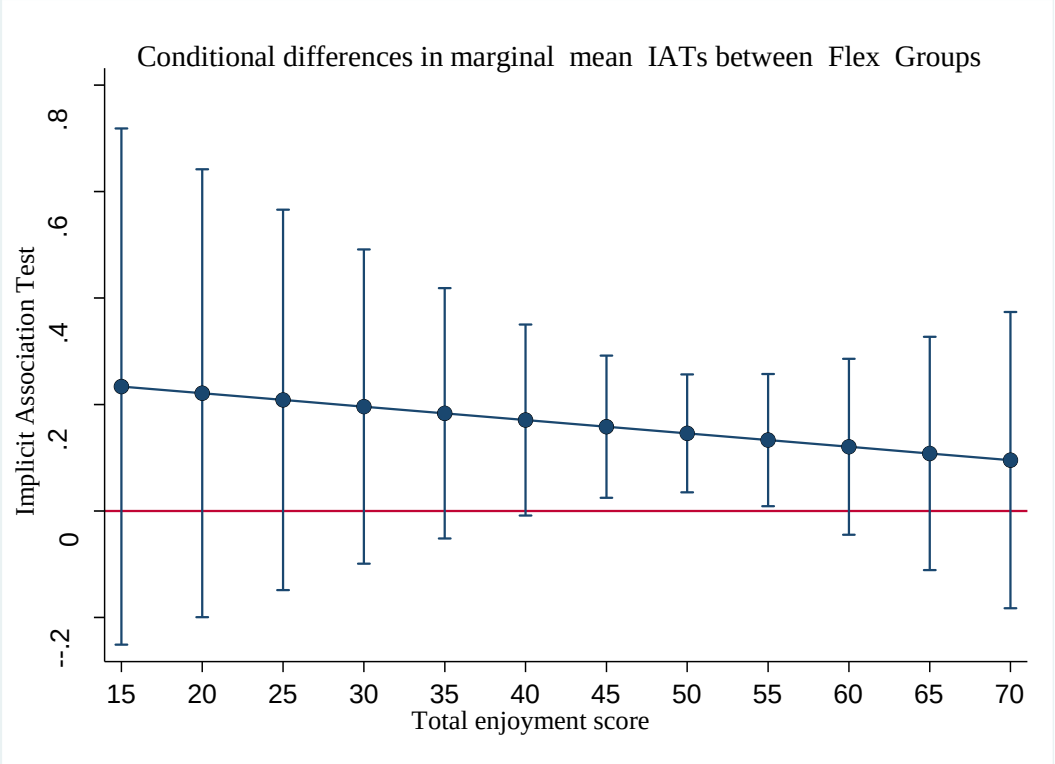


Figure 3: Differences in marginal mean IATs between Flex groups



3.5.4 Process evaluation survey

A total of 48% of the sample gave the Flex app a star rating of 4 out of 5 and 16% giving it a rating of 5. In terms of real-world experience, 35% of people found that the app was easy to incorporate into daily life with less than <1% of people finding it very difficult. A total of 61% of people stated that they had not spoken about the app to anyone around them and 69% of people responded with a ‘maybe’ when asked if they would continue to use the app after the study was over. It was also found that participants who enjoyed Flex, did so because it was simple, entertaining, had high quality graphics and they liked the games. It also revealed that for participants that did not like the app because they were bored, did not like the games, found the app slow and did not like the design of the app [Table 4].

Table 4: Key themes of enjoyment and frustration from process evaluation survey

Experience	Themes	Frequeny (no)	Percentage (%)	Quotes
Enjoyment	Simple App	46	15.98	'easy to navigate' 'easy to play' 'easy to use' 'easy user interface'
	Graphics	31	10.76	'quality graphics' 'visuals were appealing' 'bright and colourful' 'simple layout'
	Entertaining	61	21.18	'fun and interactive' 'games were interesting' 'fun games' 'variety and challenging'
	Game Characteristics	174	60.42	'the games were challenging' 'quick games' 'fun and addictive games' 'simple games'
Frustration	Bored	41	14.24	'bored quite quickly' 'only four games' ' lack of levels in some parts' 'repetitive'
	Games	81	28.13	'some games were unnecessarily slow to finish' 'games got a bit boring' 'not much variety' 'some games got increasingly hard very fast'
	App is slow	41	14.24	'took a long time' 'the app is a little slow' 'slow response time' 'slow to load'
	App design	84	29.17	'small print' 'I can't shut of the sounds' 'old graphics' 'the lack of instructions for each game'

3.6 DISCUSSION

3.6.1 Principal findings

This nested study, aimed to firstly examine the role of enjoyment acting as a moderator and potentially amplifying the significant and positive conditioning effect observed during the Flex RCT at the 24-hour follow-up period, and secondly use a process evaluation survey to evaluate if people enjoyed 'Flex' and determine real-world suitability of the app.

The average total enjoyment score for the questionnaire was high for participants in both groups. It was thought that if participants enjoyed playing the Flex experimental version of the app, this would amplify the conditioning effects of the physical activity stimuli within the Flex experimental version, as oppose to Flex control which did not have any physical activity stimuli, and hence did not have any implicit messages to condition and hence amplify.

Inspection of the results using linear modelling revealed that the positive conditioning effects observed in the randomised controlled study were not moderated by enjoyment. This may have been due to several reasons. Firstly, it is important to note that some of the games contained within the Flex app were similar in design to the IAT, which was used as a measurement tool. Both the Flex games and the IAT had been designed to influence approach-avoidance tendencies. It is possible that enjoyment may have been linked to skill and correlated to success in both the app and IAT. This is likely to have worked in one of two ways; 1) through playing the app, participants may have developed more skill towards the measurement task (IAT), or 2) participants may have

been skilled gamers who had been repeatedly exposed to the types of games (approach-avoidance) as Flex in the past and had a greater proficiency for these types of tasks. Therefore, at higher levels of enjoyment, distinguishing the conditioning effect may have become difficult because participants may have been good at playing the games and either through the practice-effects of playing the games or being previously skilled gamers may have scored better on the measurement IAT tool.

Interestingly, we found a difference between groups at lower levels of enjoyment (45-55). This could be because at this level, the conditioning effect may in fact be observable, beyond any skill effect. It seems like conditioning still actually does work when enjoyment is low. Therefore, enjoyment might not influence the level of conditioning directly but indirectly through skill. Further exploration of this data was beyond the scope of this study but further analysis through a properly powered study that uses a different measurement task than the IAT such as the single association test (SAT)(99) or the Extrinsic Affective Simon Task (EAST)(100) which use different methodologies for assessment may be useful. These tasks may be better suited to teasing out the effects of skill on enjoyment.

Another possible explanation of why an interaction effect wasn't observed could be due to the effects of usage through a dose effect. It is possible that instead of enjoyment working by an amplification of the conditioning effect, it may have had an effect through the usage pathway. Participants were advised to play the games 18 times, however, there were some participants that played the games either more or less than advised. If participants were enjoying the game, they may have been more inclined to keep playing, thereby increasing their dose of the condition stimuli and hence scoring

better on the IAT. Conversely, if they played less than advised they may not have gotten enough of dosage of the conditioning messages. At the time of this analysis usage data was not available to test for this relationship, it is hoped that future analysis will allow the research group to investigate this hypothesis by using usage as a control variable to our existing model.

Participant boredom is often reported as a common criticism of automatic processing tasks due to their repetitive nature. Research by Hsu and Lu et al. (101) has highlighted that that social norms, attitude, and flow experience explain about 80% of user acceptance of game playing whilst Choi, and Kim et al.'s (102) results suggest that people continue to play online games if they have optimal experiences while playing the games. It should be noted that effectiveness and use of gamification elements was not measured directly in this study; however, the process survey provided some valuable insights into some gamification elements.

Participants reported that they enjoyed the graphics, the competitive nature of the app and the different levels of the games. Gamification elements that participants found frustrating included the sound effects, having no game count displayed and having time limits on the games. Recent studies in the field of gamified automatic processing tasks have found mixed findings in terms of effectiveness(12, 14, 33, 34, 45), this study was able to add to the wider literature by showcasing an app with gamified elements could cause changes to automatic processing, and that generally elements of gamification were well received (Table 4).

In terms of real-world suitability, the cohort of participants were a fairly young adult population (exp. $\mu = 34.0 \pm 10.8$) and were all quite apt at using digital technology, rating themselves as 'very confident' with being able to use digital technology. In addition, the app was generally rated quite highly amongst participants, with 48% of participants giving the app a star rating of 4 out of 5, and 16% giving it a rating of 5; the majority of participants reported that they would continue to use the app when the study was over. Insights from the process evaluation survey are highly promising for implementation and usability of the Flex app, as it appears that overall the app was generally well received by participants.

3.6.3 Limitations

There were noted limitations to this study. To measure automatic processing, an IAT was used, although this is a good test for capturing automatic evaluations, it is possible that the test was not as sensitive at capturing approach/avoidance bias which some of the games targeted. The reasoning behind the use of the test was due to it being commonly used in the field, and it was thought that use of more than one test would increase participant burden. Additionally, the study was short and made up only two data acquisition time points of 2-hours following play and 24-hours following play. It is possible that allowing for longer study durations may result in better reception of the condition messages of Flex. There was also no behavioural measure to assess if changes in automatic processing lead to changes in physical activity behaviour. A behaviour measure would have been able to provide a way to capture the translation of the messages of Flex to changes in behavioural outcomes of physical activity. There were also issues with generalisability noted, the main cohort of participants recruited into the study were young adults, on average in their early 30's and hence it should be noted

that this findings are not applicable to broader age-groups. There was also an over-representation of women in the study comprising of 87% females. It was unclear from the results why this was so, but the group hypothesised that it may have had something to do with the recruitment incentive being a grocery voucher, which may have appealed to more women than men. Future studies might look at using an incentive that is more gender neutral for an even recruitment of participants.

3.6.4 Future Directions

Finding a way to unlock the effects of enjoyment on games could drastically improve and assist with targeting behaviour change interventions. Participant experience and enjoyment should always be kept in mind when designing digital behaviour change interventions(13, 43). The insights about participant frustration garnered from our process evaluation will be used to improve Flex to increase real-world suitability and adaptability. More broadly, insights about participant enjoyment and frustration may be used by other investigations in the field seeking to implement gamified digital automatic processing interventions.

Participant enjoyment is consistently reported as lacking in traditional automatic processing tasks. Enjoyment has been linked to efficacy (41), retention (42), poor data quality and may have negative effects on study outcomes(43).Both studies highlighted the potential of gamification to assists with participant enjoyment. Gamified health interventions are being increasingly developed and used to target a range health conditions as highlighted by the scoping review, and one of which is the Flex study. Although there are mixed findings on the effectiveness of these tasks in real-world settings, and even less information on elements of gamification that have an impact on

the effectiveness of these tasks it is crucial that this work be further investigated. It is important that future research investigate how gamification can be used effectively and in a manner that maintains the integrity of the automatic processing task. It is an important engagement strategy, and if implemented correctly could increase enjoyment of traditionally mundane tasks which may then have flow on effects by enhancing and amplifying the conditioning effects of the tasks.

The next obvious step for our research group would be to conduct another study to see if this change can translate into behavioural outcomes. The field in general is lacking in studies measuring changes to behaviour as a result of changes to automatic processing (28, 32, 33, 38). The need for a behavioural outcome in studies targeting automatic processing is crucial for development of the field, it is important to measure the tangible changes to behaviour that can be achieved with these tasks and future studies should seek to incorporate some sort of behavioural measure into their interventions for relevance to translation.

It is also important to understand the longevity of automatic processing tasks for creating behavioural changes long-term. The literature suggests that long-term effectiveness of health interventions is hard to achieve (103), but primarily most health interventions target the reflective processing pathway singularly (9, 58). Interventions that target automatic processing pathways may have different outcomes on longevity due to them targeting much deeper unconscious cognitive levels. Interventions should seek to understand if targeting automatic processing pathways result in longevity of intervention effects.

3.7 CONCLUSION

This study found that although Flex has the ability to favourably change people's automatic processing towards physical activity stimuli, this relationship was not moderated by enjoyment. Enjoyment did not appear to modify the conditioning effect on automatic processing observed. However, enjoyment may still be important to consider for encouraging participant usage of Flex and other automatic processing gamified apps. Our process evaluation results provide some insight into how future studies may improve upon enjoyment. FLEX, and similar apps, have the potential change peoples biases towards a range of health behaviours and offer promising and novel solutions for future health message delivery.

APPENDIX 1 Instrument for Measuring Enjoyment of Computer Game Play Version 5

Affect

I feel unhappy when playing this game.

I feel worried when playing this game.

I feel happy when playing this game.

I feel exhausted when playing this game.

I feel miserable when playing this game.

Behaviour

I talk to myself when playing this game.

I make loud comments even if nobody is around when playing this game.

I swear when playing this game.

Cognition

Playing this game or interacting with its character(s) makes me more intelligent.

The activities in this game or the actions of its character(s) are respectable.

The activities in this game or the actions of its character(s) are decent.

APPENDIX 2 Process Evaluation Survey

Instructions:	Please provide an honest answer to the questions below by either circling the appropriate response ranging from 1(not confident) to 7 (very confident) or providing a written response.

Task self-efficacy

Not Confident Very Confident

1 2 3 4 5 6 7

How confident are you that you can download an app?

Not Confident Very Confident

1 2 3 4 5 6 7

How confident are you that you can use an app?

Not Confident Very Confident

1 2 3 4 5 6 7

How confident are you that you can use an app on a daily basis?

Not Confident Very Confident

1 2 3 4 5 6 7

User Evaluation

What were the best things about the FLEX app?

What were the worst things about the FLEX app?

Were there elements of the FLEX app that you found enjoyable? If so, what were they? they?

Were there elements of the FLEX that you found frustrating? If so, what were they?

How many stars would you give the FLEX app? Why?

Do you have any recommendations for improving the FLEX app?

Real-world Experience

How easy/difficult was it to fit playing the app into your day-to-day routine? Why was this?

Have you talked about the app with anyone else? If so, who?

Will you keep using this app after the study is over? Why/why not?

Appendix 3: Process evaluation survey of participant experience using the Flex App

Enjoyment Constructs	Questions
User Evaluation (Open-ended questions)	What were the best things about the FLEX app? What were the worst things about the FLEX app? Were there elements of the FLEX app that you found enjoyable? If so, what were they? Were there elements of the FLEX that you found frustrating? If so, what were they? How many stars would you give the FLEX app? Why? Do you have any recommendations for improving the FLEX app?
Real-world Experience (Likert scale and open-ended questions)	How easy/difficult was it to fit playing the app into your day-to-day routine? Why was this? Have you talked about the app with anyone else? If so, who? Will you keep using this app after the study is over? Why/why not?

CHAPTER 4

General discussion

4.1 DISCUSSION

The two studies in this thesis focussed on exploring computerised automatic processing tasks and their use in digital psychological health interventions in real-world settings amongst adults. The first paper aimed to review the current evidence-base around efficacy of automatic training tasks, types of training tasks commonly used, mode of delivery and impacts of gamification on automatic processing tasks among adults through the use of a scoping review. The second paper aimed to evaluate the role of 'enjoyment' acting as a moderator in contributing to the positive and significant conditioning effect observed in an effective gamified automatic processing app called 'Flex.' The final section of this thesis will provide a summary of the main findings, followed by a discussion of the strengths and limitations of the included studies, the implications of the findings for practice, and recommendations for future research.

4.1.1 Main findings

Study 1

Study 1 synthesised trials evaluating the current evidence-base around the efficacy of automatic training tasks, types of training tasks commonly used, mode of delivery and impacts of gamification on automatic processing tasks for health interventions in real-world settings amongst adults. The comprehensive search of the literature found 14 studies that met all inclusion criteria. There was a wide variety of health outcomes targeted with the most prevalent being alcohol abuse followed by social anxiety. The review concluded that there were mixed findings of effectiveness, with just under half of studies showing significant improvements in automatic processing. Attentional bias

modification tasks were the most commonly used type of automatic processing task and use of smartphone technology to deliver interventions was found to be increasing.

Only two studies targeted both automatic and reflective processing pathways, even though the literature has consistently drawn attention to the need to target both pathways for optimal effects in changes to behaviour (9, 58). The review also found that there was a lack of studies evaluating how changes to automatic processing translated to changes in behavioural outcomes. For the studies that incorporated a behavioural measure (n=11), long-term follow-up was an issue with the longest follow-up period being six months (n=1).

Gamification was suggested as a way to increase participant enjoyment by several studies, however, only three studies in the scoping review actually incorporated elements of gamification into their interventions (34, 69, 78). Two of these studies found positive effects on study outcomes with the use of games and gamified elements in their interventions (69, 78). However, the effect that gamification had on influencing these outcomes was not investigated, while the third found that the gamified automatic processing task did not improve participants' motivation to train. In fact, some aspects of motivation appeared to deteriorate rather than improve, suggesting that gamification could have drawbacks if not done optimally (34). The mixed results of the use of gamification are similar to findings from other reviews in the area. They have also highlighted that attention need to be given to what gamification elements are added and when they are used (33, 35, 46, 84).

Study 2

Study 2 evaluated the role of enjoyment in contributing to the conditioning effect observed in a successful randomised controlled study of a gamified automatic processing task at the 24-hour follow-up point. There were 254 participants in the study at the 24-hour follow-up period Flex experimental (n=126) or control (n=128). All participants completed an automatic processing assessment via an implicit association test, Fang et al. (2010) *'enjoyment of computer game play'* questionnaire and a process evaluation survey.

The moderation interaction was not statistically significant (p=0.709), so there was limited evidence to suggest that the effect of enjoyment on IAT scores differed between control and Flex experimental groups. Hence, the change in IAT which was observed in the main RCT was not moderated by enjoyment. Enjoyment has been linked to efficacy (41), retention (42), data quality and having negative effects on study outcomes (43). Automatic processing tasks are also inherently 'boring' in nature, unlocking the benefits of enjoyment in these tasks is still thought to be valuable, and should still be further investigated to optimise the field. Although no moderator effect was seen for enjoyment, it was thought that enjoyment may be indirectly acting through two indirect measures of enjoyment: skill and usage.

It was thought that skill related to a potential practice-effect. Both the Flex games and the IAT have been designed to influence approach-avoidance tendencies, and operate on the same fundamental principles. It was noted that although not statistically significant overall, there were greater differences between groups at the lower end of enjoyment.

Specifically, the range of enjoyment scores between the ranges 45-55 exhibit significant results. It is possible that enjoyment may be linked to skill and correlate to success in both the app and IAT. Therefore, at higher levels of enjoyment, distinguishing the conditioning effect becomes difficult because participants may be good at playing the games and through practice-effects of playing the games, they may be better at the IAT. This might explain why there is a difference between groups at lower levels of enjoyment. At this level, the conditioning effect may be observable, beyond any skill effect.

In terms of usage, participants were advised to play the games 18 times, however this was not monitored by the research team. It is possible that some participants played the games more than advised or conversely less than advised. This may have impacted upon final conditioning through a dosage effect. Increase levels of using of the Flex app may have provided a higher dosage of the games, and subsequently their messages (approach avoidance/evaluative conditioning). Participants in the Flex experimental group were intentionally being conditioned with messages to approach physical activity stimuli whilst the control group were not being conditioned to do so. Theoretically, participants in the Flex experimental group who had higher usage of the games should have higher levels of automatic processing than as compared to participants in the control group who have high usage of the games. Further exploration of the effects of skill and usage on conditioning were beyond the scope of the thesis, however should be explored to evaluate any indirect influences of enjoyment.

The process evaluation also revealed key insights into participant experience with Flex app. They are also promising results for the use of gamification, as many elements that the participants reported that they enjoyed mapped back to elements of gamification.

Hence, whilst the RCT revealed that Flex has the ability to favourably change people's automatic processing to physical activity; our nested study revealed that this relationship was not moderated by enjoyment. Participant enjoyment while using the app did not seem to modify the conditioning effect on automatic processing. However, enjoyment may still be important to consider for future research in encouraging participant usage of the Flex App. Our process evaluation results provide some insight into how future studies may improve upon enjoyment by targeting elements that participants found frustrating including slowness of the app and app design. More broadly, these findings could inform the development and tailoring of existing or future digital automatic processing tasks using similar digital gamified designs in their health interventions.

4.1.2 Strengths and Limitations

There were several strengths to these two studies. The studies conducted within this thesis were conducted in a systematic manner. The first of the studies, the scoping review was guided by Arksey and O'Malley (87) and Colquhoun's et al.'s (86) best practice guidelines for the synthesis of scoping reviews. The second study, 'enjoyment' as a moderator of the Flex app was guided by the use of a validated questionnaire from Fang et al. (97) and the research groups own expertise in the development of process evaluation surveys based on previous research. Through this process, extensive research was done in the field of digital automatic processing tasks with the use of a comprehensive search of the literature as well as implementing and evaluating a randomised controlled study with statistical power to enable inferences of the target population group. A cross-institutional and multi-disciplinary team provided advice and guidance at each step ensuring that scientific rigour and quality was upheld.

However, the studies were not without their limitations and hence the results of these studies should be considered with caution when interpreting the results and conclusions. First, as the scoping review only focussed on the results of real-world investigations amongst adult populations and key studies in the area that had different target groups were not included. There are several studies in the field of automatic processing that target adolescences, it is possible that these studies might collectively hold key insights around efficacy, usability and delivery that may have been missed due to the review targeting only adult populations. Hence, there is a lack of generalisability with this adult focussed scoping review and the results should be interpreted with caution when applying the findings to the whole field. Second, although evidence was provided on available studies, no commentary was given on quality of included studies by way of a risk of bias assessment. Scoping reviews are much more focussed on attaining all the available evidence, including unpublished and grey-literature, in the field rather than assessing for quality(86, 87). As digital automatic processing tasks are fairly novel, it was thought that a scoping review would garner the greatest amount of information. Third, no behavioural measure was included in the study to assess if changes to automatic processing of physical activity stimuli led to significant changes in physical activity behaviour. Finally, the moderator study recruited a large proportion of women as compared to men. This may have been caused by the way the study was advertised online to participants, a small reimbursement for time to the value of $15 for Woolworths was given to participants after they completed the study. It was thought that potentially this reimbursement may have appealed more to females than males. The over-representation of women in the study may have skewed the results of the study.

4.1.3 Public health significance and implications for practice

Both studies included in this thesis provide valuable insight to a field currently lacking in evidence in real-world settings amongst adult populations. Digital automatic processing tasks have the potential to change people's biases towards a range of health behaviours and conditions and offer promising and novel solutions for future health message delivery.

Flex was a gamified automatic processing task targeting physical activity, although no behavioural measure was included in the study, the ability to change people's automatic processing towards physical activity is a significant stride forward in the realm. The next obvious step for our research group would be to conduct another study to see if this change can translate into behavioural outcomes. The field in general, as highlighted by the scoping review, is lacking in studies measuring changes to behaviour as a result of changes to automatic processing.

The scoping review also revealed that automatic processing tasks are predominately being delivered online in real-world settings. This represents an opportunity to deliver automatic processing health interventions via a low-cost pathway. The online nature also means that these interventions could be delivered to a larger scale audience. Researcher burden would be minimised by not having to incur direct research costs such as time spent recruiting, screening participants and reducing or completely getting eliminating the need for face-to-face interaction during the study; as these elements could all be completed online. In addition to this, participant burden of having to travel to locations for studies, committing to meeting researchers at specific times would also

be minimised as the online nature of the studies would provide participants an opportunity to complete the tasks at a time and location that suited them. Flex was able to put some of these principles into practice, the entire study was completed online for all phases which made the entire trial incredibly efficient.

Further to this, valuable information was gained by the process evaluation contained within Flex about elements of the gamified Flex app that they enjoyed and did not enjoy. This represents an opportunity to not only improve Flex but valuable information to other studies in the field seeking to conduct a similar type of investigation and what elements they should focus on do to increase participant enjoyment, which may eventually translate to efficacy for their interventions.

The research contained within this thesis has strengthened an evidence base currently lacking in methodologically rigorous evidence. Automatic processing tasks have a capacity to contribute positively to changing people's health behaviour, the use of the pathway could be a missing link in contributing to the efficacy of existing health interventions which mainly focus on targeting the reflective pathway. Automatic processing tasks could have the potential to change health behaviours such as physical activity, mental health disorders and alcoholism as highlighted in the scoping review and may even prevent morbidity and premature mortality.

4.1.4 Future recommendations

Future research should continue to investigate how automatic processing computerised tasks can be used in digital psychological health interventions to improve participant

health outcomes. Key gaps that were identified by both studies and should be further explored.

Dual-process theory highlights the conflicting and synergistic way that automatic processing and reflective processing influence each other. It was revealed in the scoping review that only two studies incorporated elements targeting both automatic processing and reflective pathways in their interventions. Flex also only aimed to target the automatic processing pathway. Both pathways have been established in the literature as being able to influence behaviour change. The literature suggests that long-term effectiveness of health interventions is hard to achieve, but primarily most health interventions target the reflective processing pathway singularly. Considering that the odds of translatability of intentions to behaviour change is only 48% (25), it is evident that there is a large chunk of the puzzle that health interventionist are missing. Targeting both elements of dual-process theory when designing interventions may be a crucial missing link for traditional health interventions and future research should further investigate these possibilities. After only being instructed to play Flex 18 times which took approximately 5-10 minutes, a change to people's automatic processing of physical activity stimuli was seen. A simple way to incorporate both the automatic and reflective pathways could be to add in a gamified automatic processing task such as Flex into interventions focusing on targeting the reflective pathway. Given the online nature of a game like Flex, adding in a task like this in between reflective tasks in a health intervention could be relatively easy way to target both the automatic and reflective pathways.

Participant enjoyment is consistently reported as lacking in traditional automatic processing tasks. Enjoyment has been linked to efficacy (41), retention (42), data quality and habing negative effects on study outcomes(43).Both studies highlighted the potential of gamification to assists with participant enjoyment. Gamified health interventions are being increasingly developed and used to target a range health conditions as highlighted by the scoping review, and one of which is the Flex study. Although there are mixed findings on the effectiveness of these tasks in real-world settings, and even less information on elements of gamification that have an impact on the effectiveness of these tasks it is crucial that this work be further investigated. It is important that future research investigate how gamification can be used effectively and in a manner that maintains the integrity of the automatic processing task. It is an important engagement strategy, and if implemented correctly could increase enjoyment of traditionally mundane tasks which may then have flow on effects by enhancing and amplifying the conditioning effects of the tasks.

Finally, the need for a behavioural outcome in studies targeting automatic processing is crucial for development of the field (28, 32, 33, 38), it is important to measure the tangible changes to behaviour that can be achieved with these tasks and future studies should seek to incorporate some sort of behavioural measure into their interventions for relevance to translation. It is also important to understand the longevity of automatic processing tasks for creating behavioural changes long-term. The literature suggests that long-term effectiveness of health interventions is hard to achieve, but primarily most health interventions target the reflective processing pathway singularly(58)(103). Interventions that target automatic processing pathways may have different outcomes on longevity due to them targeting much deeper unconscious cognitive levels.

Interventions should seek to understand if targeting automatic processing pathways result in longevity of intervention effects.

4.1.5 Conclusions

As the chronic health burden widens around the world, new and innovative health prevention efforts are needed to target existing health conditions and prevent the development of chronic diseases. Digital psychological health interventions incorporating automatic processing tasks are increasingly being delivered via online tools such as websites and apps in real-world environments and have the potential to make a positive impact on health. The findings from this research provide insights into the types of automatic processing tasks that might be most effective for adult populations as well as what elements, such as gamification, might make these tasks more effective. It is hoped that these research findings will be able to provide valuable insight to a field currently lacking in evidence in real-world settings, as well as generate a series of recommendations that might be able to be used in the development and tailoring of existing or future gamified automatic processing tasks.

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