Case Study 1: An Evidence-Based Practice Review Report

Theme: Interventions to improve social or emotional development, or mental health and wellbeing

How effective are biofeedback games in reducing anxiety symptoms in school aged children?

Summary

The development and expansion of technology as a means to support the mental health of children and young people presents a variety of opportunities to supplement and adapt traditional forms of therapeutic interventions such as cognitive behavioural therapy (CBT). An emerging area of intervention development involves applying therapeutic principles such as relaxation techniques within engaging technologies such as video games. The potential benefits of such intervention lie in user motivation and accessibility, however the efficacy of such technological interventions in addressing the mental health needs of children and young people remains unclear in this newly emerging field. This systematic literature review aims to examine how effective one particular type of video game-based intervention, biofeedback games, is on reducing the anxiety symptoms of school aged children and adolescents. Five studies met the review's criteria for inclusion, with a combined sample size of 128 participants and four specific biofeedback games employed, applying three separate biofeedback techniques. Effect sizes of findings were mostly small, with relevant findings suggesting that biofeedback games may reduce initial anxiety symptoms in children and young people but long-term effects remaining unclear. Future research examining the use of biofeedback games in anxiety in more specific child populations and with greater generalisability to the UK is recommended.

Introduction

Anxiety in School Aged Populations

Focus on the mental health and wellbeing of children and adolescents has been increasing within schools in the UK in recent years. Childhood mental health conditions such as anxiety disorders have been shown to be increasing in prevalence, with major surveys suggesting not only that there has been a significant rise in the number of children who experience mental health difficulties in the past decade, but that anxiety disorders are among the most commonly reported (Sadler et al. 2018). Furthermore, the presence of anxiety symptoms in children has been associated with various long-term outcomes, including low academic achievement (Deighton et al. 2018), emergence of co-morbid psychopathologies such as depression (Bosquet & Egeland, 2006) and behavioural issues such as externalising behaviour (Rapee, 2000).

The importance of addressing mental health in childhood and adolescence has been increasingly recognised within government policy. For example, in 2017 a Green Paper (Department of Health and Social Care and Department of Education) was developed with the aim of improving mental health support within schools. The document, entitled "Transforming Children and Young People's Mental Health Provision", put forward several proposals, including increased funding for mental health services and recommended training and leadership roles for teaching staff. Such action represents the key role that schools and relevant organisations hold in meeting the needs of young people vulnerable to the experience of commonly occurring conditions such as anxiety.

Interventions to Address Anxiety

Various approaches and interventions have been developed and applied to reduce anxiety symptoms in children and young people. Universal interventions such as psychoeducation have been shown to have positive effects (O'Reilly et al. 2018), as well as more targeted approaches for individuals with complex clinical needs, such as medication (Koen & Stein, 2011). Due to the broad spectrum of child and adolescent

need in this area, as well as the variety of mental health intervention format and delivery, the need for interventions developed and evaluated from established bases of evidence is crucial (Creswell et al. 2020).

One approach to supporting anxiety in children and young people that has been widely studied and applied is that of cognitive behavioural therapy or CBT (Podina et al. 2016). The principles of this therapy are that undesirable behaviour can be modified by adapting an individual's unhelpful thoughts and beliefs about a specific area. CBT has been shown to be a flexible, diverse form of therapy that lends itself well to a variety of intervention approaches, such as internet-based, within school settings and incorporating parental involvement (Reynolds et al. 2012).

There are, however, limitations that have been highlighted in relation to certain components of CBT (Whiteside et al. 2020). Firstly, the approach relies heavily on verbal language and communication in order to identify and discuss unhelpful thought patterns, with the implication that individuals with speech and language difficulties or social communication impairments may struggle to effectively engage with all elements. Secondly, several sources of evidence suggest that among young people and children, drop-out rates within CBT programmes are high (Whiteside et al. 2020), possibly due to low motivation amongst this population to persevere with an intervention reliant on discussion of uncomfortable thoughts. Furthermore, children who suffer from anxiety have been shown to exhibit difficulties with attention (Vasey et al. 1995). It may be that for populations of young people known to struggle with processes such as attention and motivation, alternative approaches to CBT that incorporate the evidenced principles with which it is associated should be considered. For example, it is well established that the condition of ADHD is categorised both by difficulties in maintaining and focusing attention as well as significant levels of anxiety.

Serious Games

The rapid development and availability of technology globally within recent years has presented a variety of emerging opportunities for the support and enrichment of child learning, health and wellbeing. One area in particular that has received attention is that of the development of video games with a specific purpose to enhance areas of child and adolescent functioning (Zhonggen, 2019). Such video games are commonly termed "serious games" and have been used in a variety of areas, for example as a form of virtual exposure therapy for children with specific phobias (Whiteside et al. 2020), to improve social skills in children with developmental conditions characterised by social impairment such as autism (Noor et al. 2012), and as a tool to support traditional forms of psychotherapy for young people (Brezinka & Hovestadt, 2007).

Biofeedback

The term biofeedback refers to a method of technology that measures the physiological responses of an individual, for example heart rate or skin conductivity, and feeds this information back to the individual in such a way that they are able to monitor this response and utilise the information constructively to inform their health and wellbeing (Gilbert & Moss, 2003).

Rationale for Review

While the use of biofeedback as a therapeutic intervention for child mental health has been examined within previous studies (Thabrew et al. 2018), there is less research into the use of biofeedback technology applied within a video game intervention for mental health generally in children and young people. Furthermore, the efficacy of its use within video games specifically to address anxiety in children and adolescents has not been examined within a systematic literature review. This review aims to address this gap by examining the use of biofeedback-based games to reduce anxiety symptoms in this population, rather than to reduce stress, depression or social impairment.

Review Question

How effective are biofeedback games at reducing the anxiety symptoms of school aged children?

Critical Review of Evidence Base

Literature Search

A search of the databases PsycInfo, Pubmed, Medline, ERIC (EBSCO) and Web of Science was conducted following a scoping review of the literature conducted through Google Scholar. Table 1 displays the search terms used and rationale behind their inclusion, while a visual depiction of the full literature search is displayed in Figure 1 in flowchart format. The "AND" operator was entered between each bracketed search term, as depicted below, in order to conduct a single complete search of each of the selected databases.

Table 1

Search Terms

	Search Term Used	Rationale
Term 1	(Biofeedback AND Game)	Studies for selection should involve implementation of an intervention featuring biofeedback and a game element
Term 2	(Child* OR Adolescent* OR Teen* OR Student* OR Pupil*)	Samples of participants should be children or adolescents of school-age
Term 3	(Anxiety OR Stress OR Worry)	Studies should be examining influence of intervention on anxiety, with which the terms "stress" and "worry" are often conflated

The use of an asterix (*) preceding a term within this table allowed for varied endings of the term in question to be searched. For example, “teen*” allowed for the inclusion of terms such as “teenager”, “teenagers” and “teens” within a search.

Screening Process

The initial database search returned 93 articles. Of these, 50 were identified as duplicates and removed. Screening of the remaining 43 article titles allowed for 19 to be further excluded in line with the inclusion and exclusion criteria detailed in Table 2. This allowed for 24 article abstracts to be screened further in accordance with the same criteria, after which 15 further articles were excluded. Of the remaining 9 articles, 4 were excluded after full text screening. One further study was identified through ancestral search but was excluded at full text screening. The final remaining 5 studies were included for analysis within the review and are described fully in Table 3. A full list of studies excluded after abstract and full text screening is included in Appendix A.

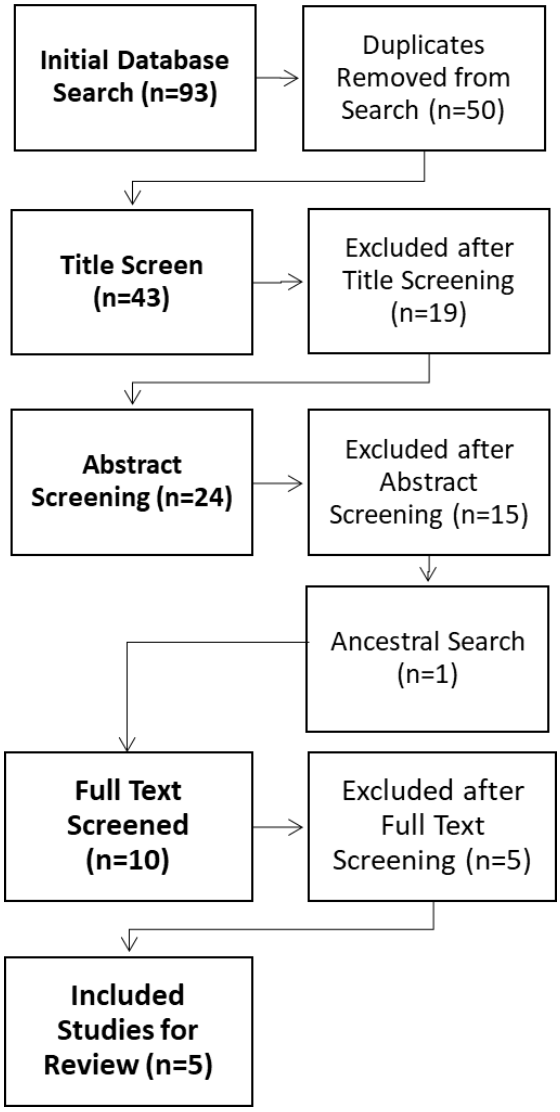

Figure 1: Flowchart of Literature Search

Table 2

Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria	Rationale
1.) Type of publication	Peer reviewed journal	Articles not published in peer reviewed journals Conference articles Dissertations	Research subjected to scrutiny indicates a standard of quality and legitimacy desirable for review.

2.) Type of Intervention	Biofeedback video game	Video game intervention with no biofeedback element Biofeedback intervention without game element	The review aims to examine the efficacy of video games using an element of biofeedback.
3.) Study Outcomes	At least one outcome measure of anxiety symptoms (pre and post-intervention implementation)	No outcome measures of anxiety	The review question aimed to examine the effect of biofeedback games on anxiety symptoms of children and adolescents.
4.) Participant Age	Of an age to attend school, including post-16 provisions, in the UK, 4-19 years old.	Older than 19 years or younger than 4 years old.	The review question focuses on the efficacy of biofeedback games in child and adolescent populations specifically.
5.) Participant Difficulties	Screening of sample for anxiety symptoms	No screening for anxiety symptoms	The review focuses singularly on the use of biofeedback in games to reduce symptoms of anxiety.
6.) Design	Quantitative studies	Qualitative studies	Research employing quantitative methodologies allows for a quantitative measure of change before and after intervention implementation that supports the aim of the present review's research question.
7.) Language	Studies written in English	Studies not written in English	Reviewer's understanding extended only to English language

Table 3

Final Studies Included in Review

References
1. Bossenbroek, R., Wols, A., Weerdmeester, J., Lichtwarck-Aschoff, A., Granic, I., & van Rooij, M. M. (2020). Efficacy of a virtual reality biofeedback game (DEEP) to reduce anxiety and disruptive classroom behavior: Single-case study. *JMIR Mental Health*, *7*(3), e16066.

2. Knox, M., Lentini, J., Cummings, T. S., McGrady, A., Whearty, K., & Sancrant, L. (2011). Game-based biofeedback for paediatric anxiety and depression. *Mental Health in Family Medicine*, *8*(3), 195.

3. Scholten, H., Malmberg, M., Lobel, A., Engels, R. C., & Granic, I. (2016). A randomized controlled trial to test the effectiveness of an immersive 3D video game for anxiety prevention among adolescents. *PloS one*, *11*(1), e0147763.

4. Schuurmans, A. A., Nijhof, K. S., Engels, R. C., & Granic, I. (2018). Using a videogame intervention to reduce anxiety and externalizing problems among youths in residential care: an initial randomized controlled trial. *Journal of Psychopathology and Behavioral Assessment*, *40*(2), 344-354.

5. Schuurmans, A. A., Nijhof, K. S., Vermaes, I. P., Engels, R. C., & Granic, I. (2015). A pilot study evaluating "Dojo," a videogame intervention for youths with externalizing and anxiety problems. *Games for Health Journal*, *4*(5), 401-408.

Mapping the Field

As outlined above, a systematic search and screening of relevant online databases identified five studies for inclusion within the scope of this review. Each of the included studies implemented and examined at least one biofeedback game for a sample of school-age participants and assessed the impact of the intervention on anxiety symptoms. A summary of the key characteristics of the included studies is provided in Appendix B.

Weight of Evidence

The five included studies were critically assessed using Gough's weight of evidence (WoE) framework (Gough, 2007) which recommends the examination of three dimensions; methodological quality (WoE A), methodological relevance (WoE B) and topic relevance (WoE C). Scores for each of these three weights were then averaged in order to give a summary ranking of the overall quality and relevance of each study in relation to the review question (WoE D). A summary of scores for each study is given in

Table 4, with full descriptions of the weight of evidence assessment given in Appendix C. Completed coding protocols for WoE A are given in Appendix D.

Table 4

Weight of Evidence Scores for Included Studies

Study	WoE A	WoE B	WoE C	WoE D
Bossenbroek et al. (2020)	Moderate (2)	Moderate (2)	Moderate (2.0)	Moderate (2.0)
Knox et al. (2011)	Moderate (2)	Moderate (2)	Moderate (2.2)	Moderate (2.1)
Scholten et al. (2016)	High (3)	High (3)	Moderate (2.4)	High (2.8)
Schuurmans et al. (2015)	Low (1)	Moderate (2)	Moderate (2.2)	Moderate (1.7)
Schuurmans et al. (2018)	Moderate (2)	High (3)	Moderate (2.2)	High (2.5)

WoE scores are given as "High" if within the range of 2.4 and 3, "Moderate" if between 1.4 and 2.3, and "Low" if less than 1.4.

Participant Characteristics

A total of 128 participants were included within the five studies identified for review. The age range of the children and adolescents involved was between 9 and 18 years, in accordance with the aim of the review to examine the effectiveness of biofeedback games as interventions specifically for school-aged children or adolescents.

While all included studies met the inclusion criteria for review of utilising screening measures to exclude participants who did not meet the threshold for significant anxiety symptoms, the presentation of anxiety in participants varied significantly.

Schuurmans et al. (2018) included participants with co-morbid diagnoses of intellectual disabilities (ID) within their sample, and while the researchers report that additional analyses revealed no significant confounding effect of diagnosis within their results, they

did not report the specifics of this analysis. This lack of transparency makes it unclear whether individuals with ID may have accessed the intervention in ways that led to differences in observed outcomes.

Similarly, Schuurmans et al. (2015) included participants with both clinical levels of anxiety and externalising behaviour in the form of hyperactivity, conduct problems and issues with peers. There was a lack of focus solely on anxiety symptoms within this study, alongside a lack of clarity on the definition, frequency of occurrence and causal mechanisms behind the identified externalising behaviours of the eight participants involved in the small-n design employed by the authors. This resulted in difficulty interpreting the reported high compliance with the study and reduction in both anxiety and externalising symptoms, as the complexity of the participants' difficulties and resulting engagement with the intervention was unclear. Furthermore, there is little to support the generalisation of these results to wider populations, as well as a lack of clarity as to the adaptations to the intervention that may have been needed to fit the needs of participants with varying co-morbid difficulties. These limitations are reflected in the low WoE A ratings for this study.

Setting

Of the five studies included, four were conducted within the Netherlands (Bossenbroek et al. 2020; Scholten et al. 2016; Schuurmans et al. 2015; Schuurmans et al. 2018) and one within the USA (Knox et al. 2011). While no studies conducted within the UK were identified within the inclusion criteria of the review, all five were situated within country members of the Organisation for Economic Co-operation and Development (OECD), indicating shared economic and social infrastructures likely to generalise to a reasonable extend to that existing in the UK. This is reflected in the moderate and high WoE C ratings given to the included studies.

The focus of the review was to examine the impact of video games incorporating a biofeedback element on anxiety symptoms of participants, and as such no exclusion criteria were applied related to the setting of the intervention. The rationale for this lay in the potential of video games as therapeutic interventions in a variety of settings for young people. For example, research has identified the benefits of parental involvement in game-based intervention for addressing mental health in children as well as within school settings (Carlier et al. 2020). In order to identify as much relevant research to the present review's focus, study settings were not limited to a single format and involved school, residential and clinical settings. This is reflected in the variety of locations present within the five studies included for review.

Research Design

Various experimental designs were employed in the research included for review. Three included studies utilised quasi-experimental, group designs to compare the impact of a biofeedback game on the anxiety symptoms of a specific group compared to a control group that did not receive the intervention (Knox et al. 2011; Scholten et al. 2016; Schuurmans et al. 2018), while the two remaining studies utilised within subjects designs involving small sample sizes (Bossenbroek et al. 2020; Schuurmans et al. 2015).

Of the group-based studies, two involved randomised allocation of their participants to either the experimental or control condition (Scholten et al. 2016; Schuurmans et al. 2018). Randomised controlled trials (RCT's) are considered an indication of high quality research methodology within studies examining the causal impact of a treatment on a targeted outcome (Sibbald & Roland, 1998) which the current review defines as the impact of biofeedback interventions upon the anxiety symptoms of children and adolescents. The use of an RCT design in these two studies allowed for the control of bias, as in both cases neither researcher nor participants were initially aware of the

treatment condition they had been assigned to, and as such is reflected within their WoE A ratings.

The third group-based study employed sequential allocation of participants to experimental and control conditions, by which fifteen initially recruited participants were first assigned to receive the intervention and a further fifteen were assigned to a waitlist-controlled condition. The authors justified their use of this methodology by identifying the ways in which randomisation was not possible within their study design, citing issues with staffing as an obstacle. While the study remained limited in that the authors did not expand on the specifics of this impediment, their acknowledgement of lack of randomisation as a potential weakness and indication of their attempts to address it as such was interpreted as a methodological strength, reflected in their moderate WoE A and B ratings.

Of the five studies reviewed, only Schuurman et al. (2018) reported conducting a power analysis to estimate the sample size needed to achieve their desired effect size (a Cohen's *d* coefficient of moderate size, 0.36). The researchers achieved close to their target sample size of 40, having recruited 37 participants, and this is reflected in their high WoE A rating. By contrast, the small-n study conducted by Schuurman et al. (2015) received a low WoE A rating and the lowest overall WoE D rating of the five included studies, utilising a within-subjects design without multiple baseline measures, which could have provided an element of experimenter control and support for the efficacy of the intervention over time. The multiple baseline design has been identified as an effective method of evaluating interventions as an alternative where the randomised controlled trial is not feasible, such as with small sample sizes (Hawkins et al. 2007), and was employed and clearly described within the study conducted by Bossenbroek et al. (2020), reflected in its higher WoE A rating.

Intervention

Four games were used as biofeedback interventions within the included studies. Three studies involved the use of “Dojo”, a game involving training of relaxation techniques based on CBT principles such as progressive muscle relaxation and deep breathing (Scholten et al. 2016; Schuurmans et al. 2015; Schuurmans et al. 2018). In all three studies the game was played by participants on laptops. The biofeedback measure involved in “Dojo” is heart rate variability (HRV), a common biofeedback element measured non-invasively through use of a small sensor clip that attaches to the user’s fingertip and connects directly to hardware in order to relay HRV information to an on-screen display.

One study involved the use of the game “DEEP” (Bossenbroek et al. 2020) a recently developed virtual reality (VR) game which relays information on breathing patterns through a belted sensory strapped around the user’s abdomen during a fantasy underwater exploratory game.

The final study implemented two games with biofeedback elements; “Freeze-Framer 2.0” and “Journey to the Wild Divine”. Both are well-established problem-solving games utilising CBT based techniques such as progressive muscle relaxation to inform performance through a finger-based sensor that relays information on skin conductivity.

The heterogeneity of both types of game used and biofeedback elements employed presents a limitation to the research included for review as any significant results may not generalise across all interventions used and exact comparison between elements such as delivery methods or feasibility cannot be made.

However, certain elements were shared across the studies, such as the use of established, evidence-based biofeedback mechanisms within the intervention games. Each study utilised at least one biofeedback element that has been identified in past research to be effective in improving wellbeing when applied therapeutically (Thabrew et al. 2018; Yu et al. 2018), a strength reflected in the high WoE C ratings for this

dimension. Similarly reflected in these ratings, a shared strength between the studies was the use of biofeedback games designed with the purpose of improving anxiety in children and young people, rather than developed for general use or an alternative SEMH need such as social skills training.

Outcomes and Effect Sizes

Effect sizes for anxiety outcome measures employed by the included studies were obtained in order to compare findings that were relevant to the review question. To enable effective comparison, where possible Cohen's d calculations were performed to obtain these where the examined study did not supply the effect size. In accordance with Cohen's criteria for interpreting effect sizes (Cohen 1988), values of 0.2 were considered to represent a "small", 0.5 a "moderate" and 0.8 a "large" effect size. Due to the differences in study designs employed within the reviewed studies, two separate tabulations of effect sizes are displayed within Tables 5 and 6.

All five included studies employed at least one standardised self- and parent/carer-report measures to assess any potential changes in anxiety symptoms experienced by participants as a result of engaging with a biofeedback game.

Of the two small sample size studies, Brossenbroek et al. chose to display their analysis graphically as well as reporting quantitative data in the form of mean difference effect sizes.

Table 5

Effect Sizes of Group-Based Studies

Study Author and Year	Total Sample Size	Outcome Measure	Intervention Condition				Control Condition				Outcome	P	Effect size (d)	Descriptor	WoE D
			N	*Pre-Mean (SD)*	*Post Mean (SD)*	*Follow-Up Mean (SD)*	*N*	*Pre-Mean (SD)*	*Post Mean (SD)*	*Follow-Up Mean (SD)*					
Knox et al. (2011)	24	Multidimensional anxiety Scale for Children (MASC)	12	59.08 (13.94)	52 (6.21)	N/A	12	70.5 (12.15)	67.08 (15.02)	N/A	Significant reduction in anxiety symptoms of intervention group post implementation	<0.01	-1.31	Large	Medium
		State-Trait Anxiety Inventory (STAI; Dutch language version	12	39.25 (7.5)	33.75 (6.2)	N/A	12	42 (7.41)	42.25 (9.75)	N/A	Significant reduction in anxiety symptoms of intervention group post implementation	0.04	-1.04	Large	

Study Author and Year	Total Sample Size	Outcome Measure	Intervention Condition				Control Condition				Outcome	P	Effect size (d)	Descriptor	WoE D
			N	*Pre-Mean (SD)*	*Post Mean (SD)*	*Follow-Up Mean (SD)*	*N*	*Pre-Mean (SD)*	*Post Mean (SD)*	*Follow-Up Mean (SD)*					
Scholten et al. (2016)	138	Spence Children's Anxiety Scale Self Report (SCAS; Dutch language version): Total Anxiety Score	70	0.83 (0.33)	0.74 (0.33)	0.72 (0.30)	68	0.86 (0.31)	0.78 (0.37)	0.71 (0.35)	No significant difference between control and intervention groups pre and post intervention	0.724	-0.02	Small	High
												<0.01	-0.39	Small	
											Significant decrease in anxiety symptoms in intervention group pre and post intervention	<0.01	-0.46	Small	
											Significant decrease in anxiety symptoms in intervention group at follow up				

Spence Children's Anxiety Scale Self Report (SCAS; Dutch language version): Personalised Anxiety Score	70	1.29 (0.53)	1.13 (0.54)	1.08 (0.53)	68	1.38 (0.49)	1.22 (0.53)	1.08 (0.53)	No significant difference between control and intervention groups pre and post intervention	N/A	No effect	N/A
										0.457	No effect	N/A
									No significant difference between control and intervention groups at follow up	<0.01	-0.43	Small
										<0.01	-0.56	Moderate
									Significant decrease in anxiety symptoms in intervention group at follow up			
									Significant decrease in anxiety symptoms in control group at follow up			

Study Author and Year	Total Sample Size	Outcome Measure	Intervention Condition				Control Condition				Outcome	P	Effect size (d)	Descriptor	WoE D
			N	*Pre-Mean (SD)*	*Post Mean (SD)*	*Follow-Up Mean (SD)*	N	*Pre- Mean (SD)*	*Post Mean (SD)*	*Follow-Up Mean (SD)*					
Schuurmans et al. (2018)	37	Spence Children's Anxiety Scale (SCAS; Dutch language version), self-report	18	21.17 (14.55)	16.44 (16.30)	16.28 (15.29)	19	16.94 (14.83)	18.67 (16.5)	17.89 (10.50)	Significant reduction in anxiety symptoms of intervention group after implementation	0.017	0.13	Small	High
		Spence Children's Anxiety Scale (SCAS; Dutch language version), mentor-report	18	17.5 (10.60)	13.61 (9.47)	13.92 (12.15)	19	18.83 (7.94)	19.11 (7.85)	13.70 (5.72)	Significant reduction in anxiety symptoms of intervention group after implementation	0.028	0.14	Small	

Table 6

Effect Sizes of Small N Studies

Study Author and Year	Sample Size	Measure (Anxiety)	Within Subjects Comparison			Outcome	P	Effect Size	Descriptor	WoE D Rating
			Baseline Mean Score/ A0 Phase (Standard Deviation)	*Intervention Condition Mean Score/ B Phase*	*Post-Intervention Mean Score/ A1 Phase (Standard Deviation)*					
Bossenbroek et al. (2020)	8	State-Trait Anxiety Inventory (STAI; Dutch language version)	3.33 (1.41)	2.40 (1.26)	2.53 (1.01)	Reduction in anxiety symptoms of participants in intervention and post-conditions compared to baseline	N/A	-0.29	Small	*Moderate*
Schuurmans et al. (2015)	8	Spence Children's Anxiety Scale (SCAS; Dutch language version), self-report	23.25 (19.59)	N/A	16.38 (14.12)	Reduction in anxiety symptoms of participants in intervention and post-conditions compared to baseline	N/A	-0.40	Small	*Moderate*

Study Author and Year	Sample Size	Measure (Anxiety)	Within Subjects Comparison			Outcome	P	Effect Size	Descriptor	WoE D Rating
			Baseline Mean Score/ A0 Phase (Standard Deviation)	*Intervention Condition Mean Score/ B Phase*	*Post-Intervention Mean Score/ A1 Phase (Standard Deviation)*					
		Spence Children's Anxiety Scale (SCAS; Dutch language version), mentor-report	27.17 (10.09)	N/A	19.33 (9.00)	Reduction in anxiety symptoms of participants in intervention and post-conditions compared to baseline	N/A	-0.82	Large	

Findings

While all five studies reviewed reported a decrease in anxiety symptoms of participants who had engaged with the biofeedback-based video game interventions employed, there was a variation in the pattern of these results.

Knox et al. (2011), employing an experimental between subject design, reported significant reduction in anxiety symptoms for their intervention group compared to a waitlisted control group as measured by two widely used, validated self-report child measures of anxiety. Large effect sizes were obtained for these results, although the study authors note the limitations in terms of their sample sizes of 12 participants per group, restricting the generalisation of these positive findings. It could also be considered that, of the five studies reviewed, Knox et al. (2011) was unique in deploying two biofeedback videogames, both of which were developed by researchers independent to the authors themselves. An interpretation of this study's strong effect sizes and significant findings could be that there was a positive difference in the experimenters' delivery of the two more established biofeedback videogames that were used as anxiety interventions, of which the researchers were less personally familiar with when compared to the authors of the other four reviewed studies. It could be that their lack of personal bias allowed for more objective instruction to participants, which may have facilitated engagement. Another explanation could lie in the variation of games offered, which may have engaged participant attention more effectively. Further research with independent researchers evaluating all discussed games would allow insight into these hypotheses.

Schuurmans et al. (2018) similarly reported a significant decrease in anxiety symptoms in an intervention group compared to a control group that received treatment as usual for anxiety. Although sample sizes were also limited for this study, and effect sizes for results were small, the use of randomisation and data collection from both participant and

caregiver were strong methodological qualities that lend support to the evidence produced in favour of the use of biofeedback videogames to address anxiety in young people. By comparison, Schuurmans et al. (2015) indicated significant reductions in anxiety symptoms as reported by both caregiver and self-report measures after intervention, with moderate and large effect sizes respectively, but did not utilise a control group or multiple baseline measures as discussed previously. The results of this study should therefore be interpreted with caution as their generalisability cannot be assumed. Bossenbroek et al. (2020), however, did employ a multiple baseline design and found a significant decrease in anxiety symptoms in participants in post-intervention phases. Although a small effect size was obtained, the authors chosen setting of a residential specialist school presented obstacles such as scheduling unpredictability and high levels of participant need that may have impacted consistency of delivery of the intervention. Interestingly, Scholten et al. (2016) indicated a significant decrease in self-reported anxiety symptoms within both the intervention and control group of their study, although there was no significant difference in this decrease between the two groups. As this study deployed an alternative video game for use within the control group that did not involve a therapeutic element, or a biofeedback component, it was speculated by the authors that the act of playing a videogame alone may be enough to alleviate symptoms of anxiety in young people. Although effect sizes were mostly small for these results, the methodological quality of this study was reflected in its high WoE D rating. As such, while the study may not have provided evidence to suggest that videogames involving a biofeedback element present better potential for anxiety intervention than those without, the authors have nonetheless provided support for the use of videogames generally to significantly decrease anxiety, and include the use of biofeedback games within this finding.

Conclusion and Recommendations

Discussion

The aim of this review was to examine the evidence-base in support of the use of biofeedback games to reduce anxiety symptoms in school aged children, and in doing so to consider the research question of whether such games can be considered effective interventions for this population. Key findings extracted from the available research in this area include the limited research currently available within this area; the initial online database search conducted within the review process returned fewer than 100 studies to consider for inclusion. Furthermore, of the studies included for review it can be observed that there is significant variation in the type of biofeedback game evaluated, the characteristics of participants recruited, the research designs employed and the settings in which the intervention was delivered.

Limitations

Generalisability

A significant limitation to the evidence reviewed within this review lies in the difficulties generalising findings. Four out of the five studies reviewed were conducted by researchers working within the Behavioural Science Institute (BSI) of Radboud University in the Netherlands, with one researcher, I. Granic, appearing as a co-author on three papers and another, A. A. Schuurmans, on two (Bossenbroek et al. 2020; Scholten et al. 2016; Schuurmans et al. 2015; Schuurmans et al. 2018). The biofeedback games involved in this research were developed as part of projects conducted within Radboud University's "Games for Emotional and Mental Health Lab" (GEMH), an established, multidisciplinary research department of the BSI that aims to develop, design and

investigate the efficacy of video games and related technology in supporting the mental health of children and young people (Radboud University, BSI, 2021).

While the fact that the majority of the studies included for review were conducted within the same setting and research team should not be considered such a significant limitation as to disregard any potential benefits of the biofeedback games studied or positive findings produced by the authors, caution should be taken in interpreting such findings as robust evidence in favour of the use of such games as anxiety interventions. Careful scrutiny should be applied to any conclusions taken from the moderate to high weightings given to this research as assessed by Gough's framework (2007), which does not necessarily allow for research weaknesses such as the potential for experimenter bias to be identified. Independent evaluation by researchers unaffiliated with the development of games such as DEEP and Dojo would be necessary in order to support the findings produced by the GEMH team regarding the benefits of applying biofeedback, game-based technology in a way that reduces anxiety in children and young people.

Furthermore, as the field of research currently stands, the study of biofeedback games as anxiety interventions can only be viewed as limited in its potential to generalise positive findings to populations outside of the setting in which it has been most intensely evaluated. As most studies examining these games were conducted within the Netherlands, it cannot be concluded with certainty that their use and potential benefits would extend to a population of children and young people belonging to different cultures and backgrounds, such as those within the UK. The pattern of mental health provision within schools, for example, differs greatly across different European countries, with an analysis conducted in 2017 suggesting that while schools in the UK had high levels of delivery of direct mental health interventions for school aged students compared to other European countries, the Netherlands were identified as providing a higher level of support for school staff (Patalay et al. 2017). The same report presented findings that clinical psychologists were utilised to high levels within UK schools to support the mental health

of young people, while their use in schools within the Netherlands was amongst the lowest of the European countries involved within the study. Such variation in the systems of support for the mental health of children and young people across different cultures should be given weight and due consideration in any attempts to generalise findings made regarding any newly developed mental health interventions. The introduction of a biofeedback game-based intervention within a setting in the Netherlands may impact a child in different ways than the same game delivered in a similar setting within the UK due to this key difference in the way mental health support is viewed and delivered between the two cultures.

Feasibility

While the discussed evidence has suggested that biofeedback games may have a positive impact on the reduction of anxiety symptoms in school aged populations, the feasibility of implementing such interventions presents a number of obstacles. A recent large scale study investigating English school approaches to supporting mental health identified not only that factors such as child deprivation and socioeconomic status have a strong association with the experience of mental health difficulties, such as anxiety, but that schools in which a high proportion of such children are supported may struggle to access appropriate and sufficient resources and funding to provide intervention (Deighton et al. 2019). In addition to potential costs of technological intervention, the studies reviewed were unclear as to the training needs of staff implementing the game. Video game interventions for child mental health have been shown to be applicable in various settings, including within schools, clinical and home settings (Thompson et al. 2010), suggesting the potential for biofeedback games to be utilised by parents, teaching staff or clinicians. However, without evaluation into the feasibility of such implementation and clarity as to the training adults may need to support children in engaging with such

interventions, it remains uncertain as to whether this technology could realistically be implemented widely.

Specificity

Furthermore, the associations found in such research between additional factors such as socioeconomic status, ethnicity, gender and the experience of anxiety in children and adolescents raises further limitations present in the use of biofeedback games as intervention. As it stands, the current research has not fully investigated the influence of such factors on the use of this technology to reduce anxiety symptoms.

For example, survey research has shown that mental health disorders in children aged between 5 and 15 years of age are more prevalent in boys than girls (Sadler et al. 2018), although in terms of anxiety extensive research has suggested that girls experience a higher level of symptoms (Bosquet & Egeland, 2006). There is also extensive research examining gender differences in the use of video games in children and adolescents that not only suggests boys are more likely to play and enjoy online, console and computer gaming (Barnett et al. 1997), but that there are specific differences in the type of video games that children and young people of different ages prefer and are motivated to play (Greenber et al. 2010).

The significance of motivation to engage with the video game element of the considered intervention is represented in the outcome measures included in three of the studies. Therefore, factors such as gender should be taken into account and further researched to ascertain the impact that the evidenced difference between game use and preference might have upon this intervention. Furthermore, it may be that video game experience may have a significant impact upon the performance of users of biofeedback games. Spatial awareness and navigation are processes intrinsic in the use of video games, and have additionally been shown to present significantly differently in males compared to females of various ages. It has additionally been shown that individuals with experience

playing video games show greater performance on spatial learning and rotation tasks than those who do not play games, a finding which extends to female adults and children (Castell et al. 2019; Subrahmanyam & Greenfield, 2004).

Implications for Educational Psychology Practice

As an intervention to address mental health in children and adolescents, biofeedback games represent an emerging area of technological development. The use of such games to reduce anxiety symptoms by supporting and teaching relaxation techniques with a strong basis in cognitive behavioural therapy principles has been shown to have potential benefits, however the analysis conducted within the current review has evidenced that studies with robust, objectively high methodological quality have so far found no strong effects in favour of this type of intervention for anxiety. The results of the review suggest that educational psychologists should therefore be cautious in recommending the use of this technology to schools.

Furthermore, the technology required for the use of biofeedback games, both in terms of software and technical equipment such as sensors and bespoke hardware, can be costly and of use to only one specific type of game. The targeted nature of this type of intervention means that schools will not necessarily be able to make use of purchased equipment with large populations of students, a significant consideration when the high numbers of children evidenced to experience anxiety related conditions is taken into account. Returning to the example previously highlighted of the current focus on the role schools have in supporting the mental health of young people through government initiatives such as those proposed within the 2017 Green Paper (DHSC; DfE), there is increasing pressure on schools to provide a broad range of provisions across multiple levels of student need. Critique of this governmental pressure highlights the need for a systemic, collaborative approach to mental health support between schools, NHS services and social care which recognises the strain that costly, targeted interventions

such as, potentially, could be represented by biofeedback games, may have upon under-resourced schools (England & Mughal, 2019). Evidence from teacher interviews has suggested, for example, that training on mental health issues is a key element that education staff feel should be addressed as a foundation before the implementation of targeted interventions (Shelemy et al. 2019).

Educational psychologists should therefore address and research the individual provisions and existing resources within schools before considering the application of technology assisted interventions such as biofeedback games.

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Whiteside, S. P., Brennan, E., Biggs, B. K., Vickers, K., Hathaway, J., Seifert, S. J., ... & Hofschulte, D. R. (2020). The feasibility of verbal and virtual reality exposure for youth with academic performance worry. *Journal of Anxiety Disorders*, *76*, 102298.

Yu, B., Funk, M., Hu, J., Wang, Q., & Feijs, L. (2018). Biofeedback for everyday stress management: A systematic review. *Frontiers in ICT*, *5*, 23.

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Appendix A

A.1
Table 7

Articles Excluded at Full Text Screening

Reference	Reason for Exclusion
Burkhart, K., Mason, E., & Lazebnik, R. (2018). Stress management intervention: A pilot evaluation in an urban adolescent medicine clinic. *Clinical Pediatrics*, *57*(6), 700-705.	3.) No outcome measure of anxiety
Carlier, S., Van der Paelt, S., Ongenae, F., De Backere, F., & De Turck, F. (2020). Empowering children with ASD and their parents: Design of a serious game for anxiety and stress reduction. *Sensors*, *20*(4), 966.	2.) No biofeedback element in intervention
Pop-Jordanova, Nada, and Zoran Gucev. "Game-based peripheral biofeedback for stress assessment in children." *Pediatrics International* 52, no. 3 (2010): 428-431.	3.) No outcome measure of anxiety
Amon, K. L., & Campbell, A. (2008). Can Children with AD/HD Learn Relaxation and Breathing Techniques through Biofeedback Video Games?. *Australian Journal of Educational & Developmental Psychology*, *8*, 72-84.	3.) No outcome measure of anxiety
Yahav, R., & Cohen, M. (2008). Evaluation of a cognitive-behavioral intervention for adolescents. *International Journal of Stress Management*, *15*(2), 173.	2.) Biofeedback game was not the primary intervention

Reason for Exclusion criteria relate to those described in Table 3

A.2
Table 8

Articles excluded at abstract screening

Reference	Reason for Exclusion
Culbert, T. (2017). Perspectives on technology-assisted relaxation approaches to support mind-body skills practice in children and teens: clinical experience and commentary. *Children*, *4*(4), 20.	1.) Review article
Dudzinska, E., Szymona, K., Pacian, A., & Kulik, T. (2015). Selected forms of therapy for individuals with autism spectrum disorder. *Current Issues in Pharmacy and Medical Sciences*, *28*(1), 21-23.	1.) Review article
Goodie, J. L., & Larkin, K. T. (2001). Changes in hemodynamic response to mental stress with heart rate feedback training. *Applied Psychophysiology and Biofeedback*, *26*(4), 293-309.	4.) Participants not of school age
Jafarova, O. (2005, June). Efficacy of using biofeedback game-based training in a stress-management program for undergraduates and secondary school students. In *Applied Psychophysiology and Biofeedback, 30*(2), 156-157. 233 SPRING ST, NEW YORK, NY 10013 USA: SPRINGER/PLENUM PUBLISHERS.	1.) Meeting abstract document
Jaramillo-Quintanar, D., Cruz-Albarran, I. A., Guzman-Sandoval, V. M., & Morales-Hernandez, L. A. (2020). Smart Sensor Based on Biofeedback to Measure Child Relaxation in Out-of-Home Care. *Sensors*, *20*(15), 4194.	2.) No game element
Kubik, A., Kubik, P., Stanios, M., & Kraj, B. (2016). Clinical and neurophysiological data of neurofeedback therapy in children with ADHD. *Przegląd lekarski*, *73*(3), 148-151.	2.) No game or biofeedback element
Lazareva, O., & Grebneva, O. (2000, December). Stress management at school by means of BFB computer game training. In *Applied Psychophysiology and Biofeedback, 25*(4), 268-269. 233 SPRING ST, NEW YORK, NY 10013 USA: KLUWER ACADEMIC/PLENUM PUBL.	1.) Meeting abstract article
Maricic, A., & Leang, H. P. (2005, June). Biofeedback computer game-based training. In *47th International Symposium ELMAR, 2005.* (pp. 185-188). IEEE.	1.) Conference paper

Maricic, A., Leang, H. P., Lazareva, O., & Bazanova, O. (2005, June). New biofeedback games. In *27th International Conference on Information Technology Interfaces, 2005.* (pp. 263-268). IEEE.	1.) Conference paper
Maricic, A., Leang, H., Lazareva, O., & Campbell, J. (2004, June). Cloning biofeedback games. In *Proceedings. Elmar-2004. 46th International Symposium on Electronics in Marine* (pp. 406-411). IEEE.	1.) Conference paper
Reineke, A., Sowder, E., & Gevirtz, R. (2007, May). Effects of an inter-active biofeedback game on anxiety and pain in children with cancer. In *BIOLOGICAL PSYCHOLOGY* (Vol. 75, No. 2, pp. 213-214). PO BOX 211, 1000 AE AMSTERDAM, NETHERLANDS: ELSEVIER SCIENCE BV.	1.) Conference paper
Sonne, T., & Jensen, M. M. (2016, February). Chillfish: A respiration game for children with ADHD. In *Proceedings of the TEI'16: Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (pp. 271-278).	1.) Conference paper
Thabrew, H., Stasiak, K., Hetrick, S. E., Wong, S., Huss, J. H., & Merry, S. N. (2018). E-Health interventions for anxiety and depression in children and adolescents with long-term physical conditions. *Cochrane Database of Systematic Reviews*, (8).	1.) Review article
Thabrew, H., Stasiak, K., Hetrick, S. E., Wong, S., Huss, J. H., & Merry, S. N. (2018). E-Health interventions for anxiety and depression in children and adolescents with long-term physical conditions. *Cochrane Database of Systematic Reviews*, (8).	1.) Review article
Van Rooij, M., Lobel, A., Harris, O., Smit, N., & Granic, I. (2016, May). DEEP: A biofeedback virtual reality game for children at-risk for anxiety. In *Proceedings of the 2016 CHI conference extended abstracts on human factors in computing systems* (pp. 1989-1997).	1.) Conference paper

"Reason for Exclusion" criteria relate to those described in Table 3

Appendix B

B.1

Table 9

Mapping the Field: Key Characteristics of Included Studies

Author and Country	Sample	Setting	Study Design			Measures		Game	Type of Biofeedback	Technology
			Type of Study	*Sessions*	*Follow Up*	*Anxiety*	*Other*			
Bossenbroek et al. (2020) Netherlands	N=8 with behavioural and psychiatric conditions Age range= 12-17 years	Special secondary school	Small N single group Multiple baseline (ABAB)	6 (length not given) over 4 weeks.	N/A	State-Trait Anxiety Inventory (STAI; Dutch Version)	Teacher interview to identify and classify disruptive behaviour	"DEEP": Virtual Reality (VR) game that teaches deep breathing in a fantasy underwater environment	Diaphragmatic breathing	Monitor and relevant game software VR headset and custom controller Belted sensor worn around abdomen that measures breathing, integrates into gameplay and relays information to a display screen

Author and Country	Sample	Setting	Study Design			Measures		Game	Type of Biofeedback	Technology
			Type of Study	*Sessions*	*Follow Up*	*Anxiety*	*Other*			
Knox et al. (2011) USA	N=24 with clinical referrals for anxiety Age range = 9-17 years F=9, M=15	Outpatient university mental health service	Controlled Clinical Trial Sequential assignment Intervention vs Waitlist Control	8 weekly (length not given)	N/A	Multi-dimensional Anxiety Scale for Children (MASC) State-Trait Anxiety Inventory for Children (STAIC)	Children's Depression Inventory (CDI)	A) "Journey to the Wild Divine": Goal-directed, fantasy themed puzzles. Physiological responses to stress are displayed and controlled to aid goals. B) "Freeze Framer": PC programme involving goal-directed activities which become easier as displayed HRV stabilises.	A) Skin Conductance Level (SCL) B) Heart Rate Variability (HRV)	Monitor, PC and relevant game software 1-3 small skin electrodes

Author and Country	Sample	Setting	Study Design			Measures		Game	Type of Biofeedback	Technology
			Type of Study	*Sessions*	*Follow Up*	*Anxiety*	*Other*			
Scholten et al. (2016) Netherlands	N=138 assessed to have high anxiety levels with the Spence Children Anxiety Scale (SCAS; Dutch version) Age range = 11-15 year F=90 M=48	Five secondary schools	Randomised Controlled Trial (RCT) Intervention vs Alternative Intervention (Video game without biofeedback element, "Rayman 2")	6 hourly (twice a week over 3 weeks)	3 month s	Spence Children Anxiety Scale (SCAS; Dutch version)	Bespoke Yes/No Scale assessing participant expectations of intervention Pre-intervention assessment of game experience was gained through participants being required to indicate their weekly hours of gameplay	"Dojo": exposes participants to emotionally stimulating scenarios and teaches CBT-based relaxation techniques e.g. deep breathing, progressive muscle relaxation Research assistant provided standardised instruction independent gameplay by participants in subsequent sessions. A research assistant was present at all sessions.	Heart rate variability (HRV)	Laptop, headphones and relevant game software "Wild Divine" Iom PE biofeedback sensor (small custom hardware designed to attach onto user's finger and connect to PC in order to relay HRV into gameplay)

Author and Country	Sample	Setting	Study Design			Measures		Game	Type of Biofeedback	Technology
			Type of Study	*Sessions*	*Follow Up*	*Anxiety*	*Other*			
Schuurmans et al. (2018) Netherlands	N=37 with and without intellectual disability (ID) Mean age=14 years F=6 M=31	Residential care Service	Intervention vs Treatment as Usual	Eight 30 minute (twice a week over 4 weeks)	4 months	Spence Children Anxiety Scale (SCAS; Dutch version)	Strengths and Difficulties Questionnaire (SDQ; Dutch version) Bespoke Likert rating scale to evaluate user experience of intervention Bespoke Survey assessing gaming experience (number of hours of participant regular gameplay)	"Dojo"; serious video game, exposes participants to emotionally stimulating in-game scenarios and teaches CBT-based relaxation techniques e.g. deep breathing, progressive muscle relaxation Researcher and two trained research assistants guided participants through a standardised tutorial procedure before independent gameplay	Heart rate variability (HRV)	Laptop and relevant game software "Wild Divine" Iom PE biofeedback sensor (small custom hardware designed to attach onto user's finger and connect to PC in order to relay HRV into gameplay)

Author and Country	Sample	Setting	Study Design			Measures		Game	Type of Biofeedback	Technology
			Type of Study	*Sessions*	*Follow Up*	*Anxiety*	*Other*			
Schuurmans et al. (2015) Netherlands	N=8 with and without intellectual disability (ID) with clinical levels of anxiety Mean age =14.38 years F=3 M=5	Two residential Care Services	Small N single-group design. Pre-test, post-test, follow up	Eight 30 minute (twice a week over 4 weeks)	Length not given	Spence Children Anxiety Scale (SCAS; Dutch version)	Strengths and Difficulties Questionnaire (SDQ; Dutch version) Bespoke Likert rating scales to evaluate user experience of and compliance with intervention	"Dojo"; exposes participants to emotionally stimulating in-game scenarios and teaches CBT-based relaxation techniques e.g. deep breathing, progressive muscle relaxation	Heart rate variability (HRV)	Monitor, PC and relevant game software "Wild Divine" Iom PE biofeedback sensor (small custom hardware designed to attach onto user's finger and connect to PC in order to relay HRV into gameplay)

Appendix C

C.1 Weight of Evidence A: Methodological Quality

To assess for methodological quality of the studies included within the review, two separate coding protocols were used. For the three studies involving experimental, group designs (Knox et al. 2011; Scholten et al. 2016; Schuurmans et al. 2018) Gersten et al.'s (2005) coding protocol was used. Studies were given ratings of "high" (3), "medium" (2) or "low" (1) methodological quality based on the indicators recommended within this protocol, as detailed in Table 10 below:

Table 10

Gersten et al (2005) Rating Criteria for WoE A

WoE A Rating	Criteria based upon Gersten et al. (2005)
3 (High)	At least 9 essential criteria are met by study At least 5 desirable criteria are met by study
2 (Moderate)	At least 9 essential criteria are met by study Between 1 and 4 desirable criteria are met by study
1 (Low)	Less than 9 essential criteria are met by study

The remaining two studies of small sample size (n) and single case design were assessed through use of Horner et al.'s (2005) protocol, for which ratings of "high" (3), "medium" (2) or "low" (1) were also assigned to indicate methodological quality in accordance with recommended criteria. These are detailed below in Table 11.

Table 11

Horner et al (2005) Rating Criteria for WoE A

WoE A Rating	Criteria based upon Horner et al. (2005)
3 (High)	Scores averaged across coding protocol's 7 sections are greater than 2.5
2 (Moderate)	Scores averaged across coding protocol's 7 sections are between 1.5 and 2.49
1 (Low)	Scores averaged across coding protocol's 7 sections are less than 1.5

Table 12 gives a summary of the assigned ratings for each of the five studies.

Table 12

WoE A Scores for Included Studies

Experimental, Group Designs

Study Author and Year	*N (Essential Criteria)*	*N (Desirable Criteria)*	*Overall Score*
Knox et al. (2011)	9	4	2 (Moderate)
Scholten et al. (2016)	9	7	3 (High)
Schuurmans et al. (2018)	9	4	2 (Moderate)

Small N, Single Case Study Designs

Study Author and Year	*Section 1 Score*	*Section 2 Score*	*Section 3 Score*	*Section 4 Score*	*Section 5 Score*	*Section 6 Score*	*Section 7 Score*	*Overall Score*
Bossenbroek et al. (2020)	2	2	3	2	2	0	2	2 (Moderate)
Schuurmans et al. (2015)	1	1	2	2	1	0	2	1 (Low)

C.2 Weight of Evidence B: Methodological Relevance

To assess for the methodological relevance of the included studies to the review question of whether biofeedback game-based interventions are effective in reducing anxiety symptoms in children and adolescents, a set of criteria was developed and implemented involving two dimensions. Based upon a framework conceptualised by Petticrew and Roberts (2003), a hierarchy of study designs for appropriately measuring the effectiveness of an intervention was considered and applied within the first set of criteria. Secondly, in order to address the review's aim to assess the efficacy of intervention to specifically reduce anxiety symptoms, a hierarchy of outcome measures was included. The rating criteria developed are described in Table 13.

Table 13

Rating Criteria for WoE B

WoE B Dimension	Rating	Rationale
Study design	3 (High) Randomised controlled trials (RCTs)	RCT's are considered the "gold standard" in terms of assessing the causal impact of an intervention. Experimental designs without randomised allocation of participants to groups have been identified as moderately relevant to answering questions of intervention efficacy, while qualitative and single case study designs are argued to be less appropriate (Petticrew & Roberts, 2003)
	2 (Moderate) Quasi-experimental and cohort studies	
	1 (Low) Qualitative research, surveys, case-control studies and non-experimental evaluations.	
Outcome Measure	3 (High) Studies including pre- and post-measures of anxiety as well as measures of anxiety at additional points such as follow-up	To examine the effectiveness of the intervention on the anxiety symptoms of participants, relevant methodology should include comparable pre- and post-implementation measures of anxiety.
	2 (Moderate) Studies including measures of anxiety only immediately pre- and post-intervention implementation	
	1 (Low) Studies not including pre- and post-intervention implementation measures of anxiety	

For each of the five studies included for review, both WoE B dimension scores were summed and divided by two to give an average final rating score for WoE B for each study, as shown below:

$$\textbf{WoE B score} = \frac{\textbf{Study Design Rating + Outcome Measure Rating}}{\textbf{2}}$$

Final WoE B Scores were assigned the following ratings:

Table 14

WoE B Weightings

WoE B Score	WoE B Final Weighting
2.1 to 3	3 (High)
1.5 to 2.0	2 (Moderate)
1.4 or below	1 (Low)

C.2 Weight of Evidence C: Topic Relevance

To assess whether the focus of the included studies was relevant to the current review, five domains were developed and relevant criteria applied. It was considered that the profile of difficulties experienced by participants, including and relating to anxiety levels, participants' prior experience of playing video games, the specific measurement of biofeedback employed, the type of video game utilised within interventions and the study setting were significant. WoE C criteria and dimensions are given in Table 15, with WoE C scores for included studies given in Table 16. Final WoE C scores were given as the average across each of the five dimensions displayed.

Table 15

Rating Criteria for WoE C

WoE C Dimension	Rating	Rationale
1. Type of Biofeedback Game	3 (High) Game has been developed and/or evaluated in peer reviewed research as an effective intervention for anxiety in children and/or adolescents	The review aims to assess the effectiveness of biofeedback games as interventions to reduce anxiety symptoms specifically; studies involving games designed to address difficulties in children such as social skills would not be appropriate. Similarly, studies involving newly developed games not yet evaluated by independent researchers may not present desirable levels of face validity.
	2 (Moderate) Game has been developed and/or evaluated in peer reviewed research as an effective intervention for mental health	
	1 (Low) Game has not been evaluated in peer reviewed research as an intervention for mental health	
	3 (High) Studies including games with a biofeedback element of heart rate variability (HRV), respiratory feedback (RSP) or galvanic	HRV, RSP and GSR biofeedback elements of interventions to reduce stress and anxiety have been identified as used most commonly and effectively in a recent review (Yu

2. Type of Biofeedback Measured	skin response (GSR) and a direct audio, visual or interactive display of measurement to users	et al. 2018). Games which include an element of biofeedback less commonly used or studied may be less valid.
	2 (Moderate) Studies including games with a biofeedback element of heart rate variability (HRV), respiratory feedback (RSP) or galvanic skin response (GSR) with no direct display of measurement to users	
	1 (Low) Studies including games with biofeedback elements other than heart rate variability (HRV), respiratory feedback (RSP) or galvanic skin response (GSR) with no direct display of measurement to users	
3. Participant Game Experience	3 (High) Studies including a measure of participant familiarity with and prior experience of video games and a baseline measure to assess gameplay skill	The familiarity of participants to the type of game intervention used within studies will influence their engagement and experience. As the review question is interested in the role motivation may play in game-based intervention, assessing the previous video game experience of participants was a relevant consideration.
	2 (Moderate) Studies including a measure of participant familiarity with and prior experience of video games	
	1 (Low) Studies including no measure of participant familiarity with and prior experience of video games	
4. Participant Difficulties	3 (High) Participants have a primary condition of anxiety.	The review aimed to investigate the effectiveness of biofeedback game interventions on anxiety symptoms of children and adolescents generally, and as such was broad in scope in terms of the anxiety-related conditions of participants involved in included studies. However, studies involving participants screened for conditions or symptoms primarily of anxiety, for example generalised anxiety disorder (GAD), would represent most relevant topics.
	2 (Moderate) Participants experience anxiety as a co-morbid condition with one or more further difficulties.	
	1 (Low) Participants do not exhibit anxiety symptoms.	
5. Setting	3 (High) Studies based within the UK	Studies based within the UK or countries with similar sociocultural

	2 (Moderate) Studies based within an OECD country	and political infrastructures would have greatest generalisability of results.
	1 (Low) Studies not based within an OECD country	

Table 16

WoE C Scores for Included Studies

	WoE C Scores						
Study Author and Year	Dimension 1 Score	Dimension 2 Score	Dimension 3 Score	Dimension 4 Score	Dimension 5 Score	Mean Score	Weight
Bossenbroek et al. (2020)	2	3	1	2	2	2.0	Moderate
Knox et al. (2011)	2	3	1	3	2	2.2	Moderate
Scholten et al. (2016)	2	3	2	3	2	2.4	Moderate
Schuurmans et al. (2015)	2	3	2	2	2	2.2	Moderate
Schuurmans et al. (2015)	2	3	2	2	2	2.2	Moderate

Appendix D: Example Completed Coding Protocols

Coding Protocol: Gersten, R., Fuchs, L. S., Compton, D., Coyne, M., Greenwood, C, & Innocenti, M. (2004). Quality indicators for group experimental and quasi-experimental research in special education. Exceptional Children, 71,149-164.

Name of Coder: X ***Date*:** 20.01.21

Full Study Reference: Knox, M., Lentini, J., Cummings, T. S., McGrady, A., Whearty, K., & Sancrant, L. (2011). Game-based biofeedback for paediatric anxiety and depression. *Mental health in family medicine*, *8*(3), 195.

Intervention Description: “Freeze-Framer 2.0” (FF2) and “Journey to the Wild Divine: The Passage” (JWD) video games. FF2 involves the player engaging in activities such as colouring a meadow or floating in a hot air balloon, while JWD involves the player engaging in activities such as making a fire or shooting a bow and arrow in a fantasy land context. Both games purposefully use imagery and sound to aid relaxation techniques such as deep, slow breathing. The player’s breathing, heart rate and skin conductivity are measured using small skin electrodes and goal-directed gameplay is achieved by the player purposefully reducing tension through deep breathing and muscle relaxation.

Study Type: Journal article, randomised controlled trial.

Essential Quality Indicators for Describing Participants

1. Was sufficient information provided to determine/confirm whether the participants demonstrated the disability/ies or difficulties presented?

☒ **Yes –** *clear outline of referral process from mental and medical health professionals of children with anxiety symptoms to the study*

☐ No

☐ Unknown/unable to code

2. Were appropriate procedures used to increase the likelihood that relevant characteristics of participants in the sample comparable across conditions?

☒ **Yes –** *sequential assignment (random assignment not possible due to lack of trained staff)*

☐ No

☐ Unknown/unable to code

3. Was sufficient information given characterising the interventionists or teachers provided? Did it indicate whether they were comparable across conditions?

☐ Yes -

☒ **No –** *unclear who provided the intervention (training etc)?*

☐ Unknown/unable to code

Essential Quality Indicators for Implementation of the Intervention and Description of Comparison Conditions

1. Was the intervention clearly described and specified?

☒ **Yes –** clear description of the game details, biofeedback element and additional psychoeducation element

☐ No

☐ Unknown/unable to code

2. Was the fidelity of implementation described and assessed?

☒ **Yes –** session by session procedure described and included in appendices

☐ No

☐ Unknown/unable to code

3. Was the nature of services provided in comparison conditions described?

☒ **Yes** – waitlist condition was described as treatment as usual and offered biofeedback after study completion

☐ No

☐ Unknown/unable to code

Essential Quality Indicators for Outcome Measures

1. Were multiple measures used to provide an appropriate balance between measures closely aligned with the intervention and measures of generalised performance?

☒ **Yes –** MASC, CDI, STAIC

☐ No

☐ Unknown/unable to code

2. Were outcomes for capturing the intervention's effect measured at the appropriate times?

☒ **Yes –** pre and post intervention

☐ No

☐ Unknown/unable to code

Essential Quality Indicators for Data Analysis

1. Were the data analysis techniques appropriately linked to key research questions and hypotheses? Were they appropriately linked to the unit of analysis in the study?

☒ **Yes**

☐ No

☐ Unknown/unable to code

2. Did the research report include not only inferential statistics but also effect size calculations?

☒ **Yes**

☐ No

☐ Unknown/unable to code

Desirable Quality Indicators

1. Was data available on attrition rates among intervention samples? Was severe overall attrition documented? If so, is attrition comparable across samples? Is overall attrition less than 30%?

☒ **Yes**

☐ No

☐ Unknown/unable to code

2. Did the study provide not only internal consistency reliability but also test-retest reliability and interrater reliability (when appropriate) for outcome measures? Were data collectors and/or scorers blind to study conditions and equally (un)familiar to examinees across study conditions?

☐ Yes

☒ **No** – sequential assignment, test-retest and interrater reliability not given for all measures

☐ Unknown/unable to code

3. Were outcomes for capturing the intervention's effect measured beyond an immediate post-test?

☐ Yes

☒ **No**

☐ Unknown/unable to code

4. Was evidence of the criterion-related validity of the measures provided?

☒ **Yes**

☐ No

☐ Unknown/unable to code

5. Did the research team assess not only surface features of fidelity implementation (e.g. number of minutes allocated to the intervention or teacher/interventionists following procedures specified), but also examine quality of implementation?

☒ **Yes –** clear documentation of procedure of sessions for interventionists

☐ No

☐ Unknown/unable to code

6. Was any documentation of the nature of instruction or series provided in comparison conditions?

☐ Yes

☒ **No** - waitlist control group received no treatment

☐ Unknown/unable to code

7. Did the research report include actual audio or videotape excerpts that capture the nature of the intervention?

☐ Yes

☒ **No**

☐ Unknown/unable to code

8. Were results presented in a clear, coherent fashion?

☒ **Yes**

☐ No

☐ Unknown/unable to code

Coding Protocol: Horner et al. (2005). The Use of Single-Subject Research to Identify Evidence Based Practice in Special Education

Name of Coder: X ***Date*:** 20.01.21

Full Study Reference: Bossenbroek, R., Wols, A., Weerdmeester, J., Lichtwarck-Aschoff, A., Granic, I., & van Rooij, M. M. (2020). Efficacy of a virtual reality biofeedback game (DEEP) to reduce anxiety and disruptive classroom behavior: Single-case study. *JMIR mental health*, *7*(3), e16066.

Intervention Description: DEEP VR game using respiratory biofeedback to measure and display information on breathing skills to train relaxation strategies. Measured with a belted sensor which is worn around the participant's abdomen and measures expansion and contraction movement during breathing, which translates to an on-screen circle that dilates or contracts depending on the feedback received from the sensor.

Study Type: Journal, single case study ABAB design

Quality Indicators Within Single-Subject Research

Description of Participants and Settings

1. Participants are described with sufficient detail to allow others to select individuals with similar characteristics; (e.g., age, gender, disability, diagnosis).

☒ **Yes**

☐ No

☐ Unknown/unable to code

2. The process for selecting participants is described with operational precision

☒ **Yes**

☐ No

☐ Unknown/unable to code

3. Critical features of the physical setting are described with sufficient precision to allow replication.

☐ Yes

☒ **No**

☐ Unknown/unable to code

Individual Quality Rating:

☐ 3: All criteria met

☒ **2: Two criteria met**

☐ 1: One criteria met

☐ 0: No criteria met

Dependent Variable

1. Dependent variables are described with operational precision.

☒ **Yes**

☐ No

☐ Unknown/unable to code

2. Each dependent variable is measured with a procedure that generates a quantifiable index.

☒ **Yes**

☐ No

☐ Unknown/unable to code

3. Measurement of the dependent variable is valid and described with replicable precision.

☒ **Yes**

☐ No

☐ Unknown/unable to code

4. Dependent variables are measured repeatedly over time.

☒ **Yes**

☐ No

☐ Unknown/unable to code

5. Data are collected on the reliability or inter-observer agreement associated with each dependent variable, and IOA levels meet minimal standards.

☐ Yes

☒ **No**

☐ Unknown/unable to code

Individual Quality Rating:

☐ 3: All criteria met

☒ **2: Three to four criteria met**

☐ 1: One to two criteria met

☐ 0: No criteria met

Independent Variable

1. Independent variable is described with replicable precision.

☒ **Yes**

☐ No

☐ Unknown/unable to code

2. Independent variable is systematically manipulated and under the control of the experimenter.

☒ **Yes**

☐ No

☐ Unknown/unable to code

3. Overt measurement of the fidelity of implementation for the independent variable is highly desirable.

☒ **Yes**

☐ No

☐ Unknown/unable to code

Individual Quality Rating:

☒ **3: All criteria met**

☐ 2: Two criteria met

☐ 1: One criteria met

☐ 0: No criteria met

Baseline

1. The majority of single-subject research studies will include a baseline phase that provides repeated measurement of a dependent variable and establishes a pattern of responding that can be used to predict the pattern of future performance, if introduction or manipulation of the independent variable did not occur.

☒ **Yes**

☐ No

☐ Unknown/unable to code

2. Baseline conditions are described with replicable precision.

☐ Yes

☒ **No**

☐ Unknown/unable to code

Individual Quality Rating:

☐ 3: All criteria met

☒ **2: One criteria met**

☐ 1: No criteria met

Experimental Control/Internal validity

1. The design provides at least three demonstrations of experimental effect at three different points in time.

☒ **Yes**

☐ No

☐ Unknown/unable to code

2. The design controls for common threats to internal validity (e.g., permits elimination of rival hypotheses)

☐ Yes

☒ **No**

☐ Unknown/unable to code

3. The results document a pattern that demonstrates experimental control.

☒ **Yes**

☐ No

☐ Unknown/unable to code

Individual Quality Rating:

☐ 3: All criteria met

☒ **2: Two criteria met**

☐ 1: One criteria met

☐ 0: No criteria met

External Validity

1. Experimental effects are replicated across participants, settings, or materials to establish external validity.

☐ Yes

☒ **No**

☐ Unknown/unable to code

Individual Quality Rating:

☐ 3: Experimental effects are replicated across more than half of all participants and a specific setting

☐ 2: Experimental effects are replicated across a quarter of all participants

☐ 1: Experimental effects are replicated across at least one participant

☒ **0: No evidence of experimental effect replication**

Social Validity

1. The dependent variable is socially important.

☒ **Yes**

☐ No

☐ Unknown/unable to code

2. The magnitude of change in the dependent variable resulting from the intervention is socially important.

☒ **Yes**

☐ No

☐ Unknown/unable to code

3. Implementation of the independent variable is practical and cost effective.

☐ Yes

☒ **No**

☐ Unknown/unable to code

4. Social validity is enhanced by implementation of the independent variable over extended time periods, by typical intervention agents, in typical physical and social contexts.

☒ **Yes**

☐ No

☐ Unknown/unable to code

Individual Quality Rating:

☐ 3: All criteria met

☒ **2: Two to three criteria met**

☐ 1: One criteria met

☐ 0: No criteria met