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Research Article

Usability of the BigO system in pediatric obesity treatment: A mixed-methods evaluation of clinical end-users

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ABSTRACT

Objective: To assess technical usability of the BigO app and clinical portal among diverse participants and explore the overall user experiences of both.
Methods: Methods included technical usability testing by measuring the relative user efficiency score (RUS) for the app and measuring Relative User Efficiency (RUE) using the 'think aloud' method with the clinical portal. Qualitative approaches involved focus groups with adolescent app users and semi-structured one-to-one interviews with clinician participants. Thematic analysis was applied to analyze qualitative data.
Participants: Clinical participants consisted of adolescents seeking treatment for severe obesity and were invited via telephone/face to face to attend technical usability testing and a focus group. Healthcare professionals (HCPs) and researchers using the BigO clinical portal interface were invited to participate in usability testing and semi-structured interviews.
Results: From 14 families invited to attend, seven consented to join the study and four adolescents (mean age=13.8 (SD 0.8) years) participated. Additionally, six HCPs and one pediatric obesity researcher took part. RUS for adolescents indicated that the tasks required of them via myBigO app were feasible, and technically efficient. No user-related errors were observed during tasks. Technical barriers reported by adolescents included notifications of battery optimization, misunderstanding image annotation language, and compatibility challenges with certain phone models. RUS for the HCPs and researcher indicated that basic technical skills are a potential barrier for clinical portal use and qualitative findings revealed that clinical users wanted a logging option for monitoring goals and providing feedback on the portal.
Conclusion: Our study provided valuable formative findings from clinical end-users in Ireland indicating that adolescents being treated for obesity rated myBigO app as usable, acceptable and that it may assist other key stakeholders to understand food marketing and to monitor dietary and physical activity behaviors. Several key suggestions for future iterations of the clinical portal were provided to enhance its value in pediatric obesity treatment.

1. Introduction

Globally the number of children and adolescents with pediatric obesity has increased ten-fold over four decades [1]. In 2016, overweight and obesity affected more than 340 million children and adolescents aged five to 19 years [2]. In Ireland 20 % of children are living with overweight or obesity [3], with 1.8 % estimated to have severe obesity [4]. A recent systematic review of clinical practice guidelines for treating children and adolescents with obesity recommended that the cornerstone of treatment include multicomponent interventions that facilitate behaviour change in the young person and family members, and which optimize nutrition, physical activity (PA) and reduce time in

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sedentary behaviour [5]. However, few multidisciplinary childhood obesity treatment services exist in Ireland [6] or around the world and for some families, cost, time and transportation limit access to treatment services [7]. Due to the magnitude of the issue, the chronic nature of obesity [8] and the diversity of causal attributions [9], inexpensive but effective strategies that can be implemented at scale to influence large numbers of children and adolescents are crucial [10,11]. The World Health Organization [12] (WHO) emphasises the urgency of embedding new interventions into existing practice. In recent years, there has been an increase in the use of online systems such as electronic health (eHealth) [13] and mobile health (mHealth) [14] platforms. mHealth applications (apps) have the potential to reach large populations of young people in their everyday environments, as a potentially resource-efficient method of delivering health interventions [15]. The likely benefits of using mHealth to augment face-to-face interventions for behaviour change include its potential for cost efficient delivery, reduced burden on individuals, ability to adapt and personalise programmes, collection and provision of real-time data and feedback, tracking and recording self-monitoring information, and their attractive, engaging digital qualities [16]. Notably, many adolescents are effectively "digital natives", having become acquainted with computers and mobile phones early in their lives [17]. Features of apps targeting the prevention or treatment of childhood obesity include educational material, social networking opportunities, rewards/prizes and games [8, 15–18].

1.1. Technical usability and engagement testing

Despite the vast array of health and fitness apps available, few integrate evidence-based methodologies nor have they been tested for their technical usability, user engagement or user satisfaction with target end-users (particularly in vulnerable clinical populations in under-resourced clinical settings) [10]. Usability testing is a crucial step in developing valid mHealth tools to explore acceptability, to support optimal use and engagement amongst target groups and to highlight any changes or further design needed before clinical efficacy testing [18-20].

Technical usability is the extent that a product can complete certain tasks in an effective, efficient and satisfactory manner by specific users and in a defined setting [20]. Standardised measurements in technical usability testing include: efficiency (the perceived ability of the system to complete a function in an apt, effective and reasonable manner); affect (the users emotional feelings for the system); helpfulness (the sense that the system can correspond to assist in overcoming challenges); controllability (the belief that the system interacts consistently with user input); and learnability (the perception that familiarising with the system is fairly easy) [21]. However, many studies have used their own bespoke tools for assessing these variables in child and adolescent populations and there is ambiguity in the literature around agreed definitions or standardized means of assessing user experience [22].

Qualitative methods such as interviews and observation are useful in gathering detailed information on users' experiences, usage and behaviors which other approaches, including surveys or system logs cannot evaluate [23]. However, most studies find that the detail captured from these is insufficient [23]; emphasising the beneficial combination of a mixed-methods approach with both quantitative and qualitative techniques.

As illustrated in Fig. 1 below, the BigO Study [24] was a pan-European, EU-funded project (http://bigoprogram.eu, accessed on 29th July 2024) whereby children and adolescents were engaged as 'citizen scientists' to collect food and advertisement-related imagery and objective physical activity data using mobile sensors, smartwatches and a mHealth app [25]. In other words, the BigO system can be described as a healthcare-customized remote measurement technology platform (RMT) that integrates privacy and security-aware protocols by design to handle and analyze users' personal information. It should be noted that the privacy and security methods integrated into the BigO system are applicable to any data-driven RMT platform in healthcare and other sectors, where there is risk of sensitive personal information loss at any stage of the data pipeline including acquisition, storage, transmission, access, and analysis. The key design objective of the BigO system is to incorporate privacy and security protocols in the system that do not degrade the quality of data and that facilitate data analysis tasks without revealing sensitive information. The data is then transferred securely to a clinical portal, and registered healthcare professionals (HCPs) and researchers can view patient data, including physical activity data graphs, photographs of food and food marketing, and a heatmap of physical activity intensity levels around the geographical region in which the user is based [26]. A subgroup of children in treatment for obesity at a child and adolescent obesity management service were recruited from the wider BigO participant user group in Ireland and invited to test the app in an ethically approved technical usability study.

Perceived usefulness of the BigO system has already been explored [27]; however there was a gap related to evidence of technical usability which this study sought to address.

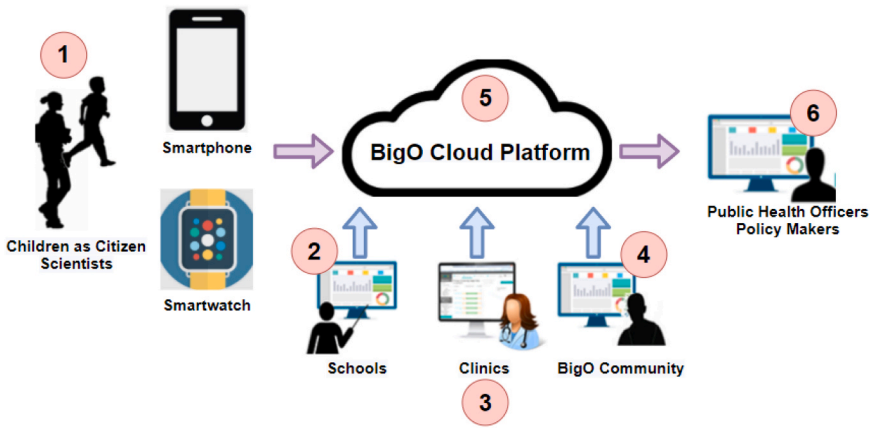

Fig. 1. Overview of the BigO system. Adopted and reproduced with permission from Eirini Lekka and 108 Monica Mars, BigO - Big data against childhood Obesity; eICDAM, 2021 [1]. Children and adolescents within an age band (9–16 years old) act as data providers using smartphones and smartwatches [2]. Teachers running the organized school efforts with students [3]. Clinicians treating patients in clinics [4]. Administrators for school, clinic, and the whole BigO platform [5]. BigO cloud data aggregation and processing [6]. Public Health officers (researchers or policymakers) evaluating children/adolescents behavior indicators in a geographical region in the combination of Local Extrinsic Conditions (LECs) relevant to obesity.

1.2. Aim

This study aimed to test the technical usability and engagement levels of the BigO app and clinical portal among children, adolescents and HCPs at one European clinical site (Children's Health Ireland at Temple Street, Dublin, Ireland). The Child and Adolescent Obesity Service in Children's Health Ireland is a Tier 3 pediatric specialist obesity service and accredited centre of excellence within the European Association for the Study of Obesity (EASO) network of Centres for Obesity Management. The objectives of this study were to 1) assess the technical usability of the BigO app and clinical portal among diverse participants and 2) explore the overall user experiences of both.

2. Materials and methods

2.1. Ethics

The research protocol was reviewed by the hospital research ethics committee in Children's Health Ireland at Temple Street, Dublin and approved (18.013) as part of the BigO study.

2.2. Recruitment and participants

Participants in the study included the target end-users (i.e., children and adolescents with obesity and healthcare professionals working in obesity treatment). Clinical participants (children and adolescent patients aged 9–16 years and their parents), already enrolled in the wider clinical BigO study in Ireland (n = 37) in 2019, were given an information sheet and invited via telephone/face-to-face to attend a voluntary technical usability assessment and a subsequent focus group. Families who provided parental consent and child assent were then sent an appointment letter for usability testing (n = 7).

HCPs and clinical researchers involved in the Child and Adolescent Obesity Management Service were also recruited. Dietitians, physiotherapists, psychologists and nutritionists that worked with or had experience of the pediatric obesity service were eligible. HCPs were contacted in person or through email informing them of the details of the study. Participant information leaflets were supplied to potential participants and informed consent forms were completed prior to commencing the study.

2.3. Data collection and analysis for the BigO app: children and adolescents with obesity in Ireland

2.3.1. Technical usability testing & relative user efficiency

Following the consent process, adolescents (n = 7), with a parent or carer, were invited to the hospital to take part in technical usability testing of myBigO app. The methods were adapted from O'Malley et al., [28] whereby Relative User Efficacy Scores (RUS) were used alongside qualitative methods in order to explore user perceptions, satisfaction and engagement. A sub-sample of four participants attended for the technical usability testing procedures which followed validated and published methods. While three of seven adolescent participants who consented did not ultimately take part in the technical usability study, such high attrition rates are common in pediatric clinical research studies [29,30].

Participants completed a study questionnaire (appendix B), which included three tasks for participants to complete using the app while being timed and audio recorded. Participants were asked to 'think aloud' while performing these tasks to capture their thought processes and views about performing these functions on the app. Tasks included registering with the BigO app, completing the introductory questionnaire, describing how users would take photos of food/beverages and food advertisements using the app and then proceeding to take photos of each of the available categories on the app including breakfast, lunch, dinner, a beverage and a food advertisement (appendix C). Quantitative data from technical usability testing and questionnaires alongside qualitative data from observation and audio recordings were used to assess the overall technical effectiveness. Quantitative data were measured as RUS [28]. RUS is calculated by dividing the novice participants time to task completion by that of an expert user of an app. Bevan [31] suggests a novice user would take 2–3 times that of an expert for completing technical usability tasks. Noted errors were categorized as either user related errors or BigO technical related errors.

2.3.2. User engagement testing

After the technical usability testing session, adolescents ($n = 4$) subsequently took part in a focus group session to discuss their overall experiences and the relative advantages and disadvantages of using the myBigO app. The focus group was moderated by a postgraduate dietetic student with a clinical dietetic supervisor who was responsible for the research, and lasted approximately 60 min. The discussion included questions that stimulated participants to explore benefits, drawbacks, barriers and facilitators of using myBigO app (see appendix D for topic guide). The focus group was audio-recorded and later transcribed verbatim. Thematic analysis (TA), with an inductive approach, was used to analyze the focus group discussion [32] so that codes and themes relevant to the research question could be identified and labelled [33]. The researchers were familiar with the adolescents participating in the focus group, as the same participants had already completed aspects of the BigO study. The testing took place within the healthcare facility that the young people had received assessments and treatments previously. The physical environment was changed, with snacks and refreshments provided and a group circle to facilitate the focus group discussion and equal participation amongst the adolescents. Parents/guardians were asked to wait in a separate area to minimise their influence on the adolescents' focus group discussion. The focus group was conducted in the evening outside of busy clinical hours and at a time that suited families participating after school/work.

2.4. Data collection and analysis for the clinical portal: health and research professionals

The methodology chosen for testing technical usability of the online clinical portal with HCPs and clinical researchers was adapted from the SmartCAT (Smartphone-Enhanced Child Anxiety Treatment) study which used an app and clinical portal similar to the BigO system [34]. The technical usability test included observed technical tasks using the 'think aloud' method described above, followed by semi-structured one-to-one interviews. HCPs and clinical researchers (n = 7) who had consented to participate were invited to attend a one-to-one session at a time convenient to them. The sessions were approximately 60 min in duration and involved three distinct stages described in Fig. 2.

2.4.1. Technical usability testing of the BigO clinical portal

The demonstration of the BigO clinical portal (detailed in appendix E) focused on a step-by-step guide on the different features of the portal. HCPs were required to complete different tasks on the BigO clinical portal. This included logging onto the portal, creating a new patient profile, and viewing and interpreting data available. The technical

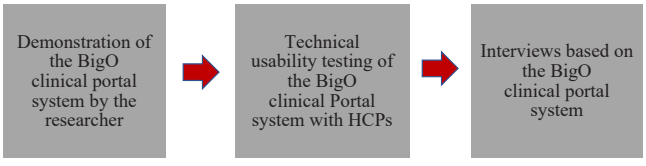

Fig. 2. Three distinct stages for testing the BigO clinical portal among pediatric health and research professionals in Ireland.

usability tests by HCPs and the expert user of the BigO clinical portal system (whose score is used as a benchmark) were timed to determine RUS and recorded using a Dictaphone. Both the technical usability test and interviews were audio recorded and transcribed verbatim. Analysis of the qualitative data from technical usability testing was carried out using an inductive thematic approach. This was implemented by coding and identifying frequent themes that were present in the technical usability testing transcripts.

2.4.2. Interviews with health and research professionals

The interviews were recorded using a Dictaphone and transcribed verbatim. The data analysis of the interviews was carried out using a deductive thematic approach [35]. This approach examined different areas of interest identified by the participants during technical usability testing and included the perceived benefits, challenges and barriers of the portal system and recommendations for further improvement.

3. Results

3.1. BigO app: adolescents

With their parents, seven adolescents (four males and three females, aged 13–16 years) consented to participation. On the day of testing, three families did not attend. Results pertain to four participants (three males and one female), with a mean age of 13.8 (SD 0.8) years. Characteristics of participants who took part in the wider BigO study (n = 37) and the four adolescents who participated in this usability study are displayed in Table 1 below.

3.2. Relative user efficiency testing: children and adolescents

As displayed in Table 2, participant time for task completion was between one and three times that of an expert user of the app. Participant comments conveyed a lack of clarity/understanding regarding some of the questions on the app and highlighted technical glitches including the need for battery optimization.

3.3. Engagement

Table 1 illustrates the characteristics of all children and adolescents participating in the BigO study at the clinical site and of those adolescents who participated in the usability study.

3.4. Qualitative findings from usability testing and focus group among children and adolescents

3.4.1. Usability and satisfaction

Participant narratives confirmed RUS data that myBigO app was easy to use and there were no user-level difficulties with navigating the app.

Table 1
Characteristics of BigO Participants. Abbreviations: BMI, body mass index; IQR, interquartile range; No., number; SD, standard deviation.

Characteristic	Total in BigO study n	Participated in the usability study
No. of participants in BigO study (Ireland) at time of recruitment n (%)	37	4 (10.8 %)
Sex and Age		
Male	18 (48.6 %)	3 (75 %)
Female	19 (51.4 %)	1 (25 %)
Mean Age (years) (SD)	13.2 (2.1)	13.8 (0.8)
Anthropometry		
Mean BMI of participants (kg/m^2) (SD)	33.04 (6.02)	34.28 (6.9)
Mean BMI SD score (SD)	3.08 (0.53)	3.06 (0.6)
Mean BMI centile of participants (SD)	99.7 (0.43)	99.6 (0.45)

Table 2
Comparison of expert user time and mean relative user efficiency scores (RUS) with participant comments for each task during technical usability testing of myBigO app.

Task	Time taken by expert user (minutes)	Mean relative user efficiency score (minutes) (SD)
Task 1: Complete registration questionnaire	1.80	1.4 (0.4)
Task 2: Show how myBigO app takes food/beverage and food ad photos	0.67	2.7 (0.4)
Task 3: Take a photo of each of the following using myBigO app and submit it: bowl of breakfast cereal, sandwich, dinner meal, cup of tea, food ad.	1.82	1.6 (0.6)

> "it was very clear. Like there's not much like instruction or anything hard that you have to do, you just take pictures, easy" -Adolescent 1, male

Participants stated they would recommend the app to their friends if "*they were overweight*" or "*struggling with their weight*" -Adolescent 4, male.

The key suggestions to improve the app addressed technical-level issues they had experienced and included making the app compatible with more phone models, more options for self-monitoring, and improving annotation functionality for the photographs.

> "what you were having like if you were having a meat or veg like carbs or whatever it was. It would do like multiple of them so you could say exactly what you were having" -Adolescent 1, male

3.4.2. Self-monitoring

Participants reported liking the self-monitoring feature of the app: "*it was kinda cool that you could see all your steps and stuff*" -Adolescent 4, male;.

"*See how healthy or unhealthy of what we are eating*" -Adolescent 2, female.

and conceptualized that their images are being captured as a means of monitoring their dietary intake to "*see like what we are eating even after we are told like. You were trying to see if we were sticking to it*" -Adolescent 1, male.

They also revealed their avoidance of submitting certain images because they perceive them as "*a really bad meal*" and they feel "*that's not what you should be eating*" -Adolescent 1, male.

Participants suggested a food diary or gallery feature that would allow them review their food and beverage images, which could support decisions about healthy eating. One participant said: *"Maybe look over it again and just double check if it's actually something that you should be eating or like see the amount that you should be eating"*-Adolescent 4, male.

3.4.3. Barriers and facilitators to using myBigO

Two social influences on app engagement were described by participants. Firstly, parents and family were considered supportive, and engagement was promoted at home "*My family was always supportive*" -Adolescent 1, male;.

[my family] *"thought it was a good idea"* -Adolescent 2, female.

On the other hand, participants did not wish to explain myBigO app to friends or peers as it was connected to the obesity management clinic. Therefore, they avoided using it when out with friends "*you just pull out your phone; it's just a bit weird like. You just wouldn't do it. And they would probably tell people at school*" -Adolescent 3, male.

Participants also stated the following as barriers for app use: forgetting about it, not having access to the phone with the app,

Table 3
Tasks performed by Health and Research Professionals. Relative User Efficiency Scores (RUS) were used to measure the mean time that it took users to complete different technical usability tasks in comparison with an expert user of the BigO clinical portal system.

Tasks required to complete	*Relative User efficiency mean and (standard deviation)*	*Comments about the tasks*
Task 1 Log into the BigO clinical portal	5.98 (6.24)	• Most participants ($n = 4$) could complete this task
Task 2 Create a new patient registration	0.93 (1.08)	• Some participants did not know how to generate a new anonymous patient code for the purpose of registering a new patient on the clinical portal
Task 3 Demonstrate functions on the patient list	1.64 (0.58)	• All of the participants ($n = 7$) incorrectly identified certain icons during the usability testing
Task 4 Access patient data: steps per afternoon	1.69 (0.91)	• This information was accessed by the majority of participants, $n = 1$ could not complete this task as they did not know where to get the information.
Task 5 Download and interpret steps per day	1.96 (0.52)	• The majority of participants could not find where this information was. The participants that found this information interpreted the data incorrectly as they could not determine the number of hours the data was based on.
Task 6 Interpret average physical activity per day	2.63 (0.99)	• Most of the participants ($n = 6$) were very uncertain of the data that they were examining. $n = 1$ could not complete this task.
Task 7 Examine the food image data	3.51 (1.85)	• Food pictures too small to examine for content. $n = 1$ could not complete this task.
Task 8 Explain the mobile questionnaire	3.29 (0.31)	• Correct interpretation of the mobile questionnaire data. $n = 1$ could not complete this task.
Task 9 Look at the heatmap and explain what you can see and how it works	2.37 (0.87)	• All participants ($n = 7$) gave a vague description of the heatmap but did not understand what was represented in it.
Task 10 Download and interpret data that is available about all patient users	1.45 (0.53)	• Most participants ($n = 6$) could download and interpret the data available on all participants. $n = 1$ could not complete this task.
Task 11 Log out of the BigO clinical portal system	3.43 (1.56)	• No issues noted.

distractions e.g., PlayStations, Xboxes and not having a photo gallery/diary option on the app.

3.4.4. Impact of food advertising

Participants indicated that food advertisements "*…have quite a big influence on us*" (Adolescent 2, female). They felt that capturing food ad images made them more aware of their individual exposure and the frequency of food ads in their living environments, as illustrated in the following quotes:

> "*When you take a photo, you notice it more like how many there actually are like you would see in a day*" -Adolescent 1, male

> "*Makes you realize how many like pictures there are of food. Like there's really a lot which is really bad cause we're seeing it a lot*" -Adolescent 2, female

The group perceived that the images captured will be shown: "*to someone with some sort of like more power*" (Adolescent 1, male) to reduce the amount of food ads in certain areas: "*see if you can get them to cut down a bit on foods ads in specific places or like taking them off buses*" -Adolescent 1, male.

Participants would like the option to view the frequency that a particular ad is seen over a defined period and suggested incorporating a food diary/gallery option to enable users to take images more instantly and upload them at a later time.

3.5. Clinical portal feedback: health and research professionals

The results of the pilot demonstration have been included as the feedback yielded valuable insight into use of the BigO clinical portal.

As such, a total of six pediatric HCPs and one researcher with a clinical background in nutrition and a research background in pediatric obesity and ehealth participated. The sample included one clinical psychologist, two dietitians, one researcher and three physiotherapists.

3.5.1. Usability of the BigO clinical portal

The results of the task-orientated usability testing of the BigO clinical portal are presented in Table 3.

3.6. Qualitative findings from health and research professionals

One interview session included two HCPs at the same time whilst the other interview sessions included one HCP per session, as it was difficult to secure appointments with HCPs working in the busy clinical pediatric setting. Seven healthcare professionals/clinical users were interviewed in total. Themes and sub-themes generated from the interview data are conveyed with illustrative quotes in Table 4 below.

3.6.1. Perceived benefits of the BigO clinical portal for childhood obesity treatment

The participants found it particularly useful to have behavioural data available about patients prior to seeing them in clinic. This included images taken of food, their activity levels, sedentary activity, sleep levels and how this information might inform them about how patients spend their time. The ability to obtain objective information for both treatment and research was considered important. Capturing food ads were considered a useful activity to highlight the obesogenic environment in which children may live and to raise awareness of the impact that food advertising has on their food choices and eating habits.

3.6.2. Barriers/Challenges of the BigO clinical portal

The engagement and adherence of patients with the BigO app and smartwatch was perceived as a challenge for HCPs.

Table 4
Summary of themes and sub-themes from health and research professionals interview data.

Theme	Sub-theme	Illustrative quote
Perceived benefits of the BigO clinical portal for childhood obesity treatment	Assessing diet, activity, sleep, sedentary activity behaviours before clinic appointments	*"I think having the information before you go to clinic for a patient that's coming in would be fantastic."*- Dietitian 1. "*it's nice as well to get an idea of the activity levels if they do wear the watch properly, if their activity levels do match what they're saying they're doing as well.*" -Physiotherapist 1
	Availability of objective information for clinic and research	"*Information on obesity and activity for children who are obese, that is a little bit more objective because as a clinician it is very difficult to get objective outcome measures in the treatment of obesity, so it is good.*"- Physiotherapist 2 *"It would be very good for research if all the information was available."- Dietitian 1*
	Food marketing images offer potential to raise awareness	*"The food ads may help to highlight to the children how susceptible they are to marketing and even open that kind of, you know, door for discussion".* -Physiotherapist 2
Barriers and challenges	Low engagement and poor adherence among children and adolescents	*"It can be very dependent upon the child as to whether or not they take part that's a big kind of barrier… there is quite a lot of them don't really engage as well with it and I think that the novelty at the beginning they get really excited by it and then they kind of forget to wear it or they haven't charged the battery up."* - Physiotherapist 1
	Low technical ability and confidence among HCPs	*"I'm a technophobe so…"* -
Recommendations for improvement	Connections between systems: (1) Option for communication between HCPs and patients and (2) Portal connects with patients' healthcare records	*"It would be nice as well to be able to give some sort of feedback to the kids and be like well actually yeah last month this is your activity and this month this is your activity, just to give them that motivation."- Physiotherapist 1* and *"If we could log their goals …even at group or when they come into group, if their goals were being logged …. "-Psychologist 1*
	Improve current graph presentation for ease of interpretation – [1] explicit graph labelling / explanations and[2] provide normative graphs for comparison	*"I think that some of the graphs might need a few more labels maybe or maybe little explanations at the side of them, just because there are so many of them.some people are quite visual and graphy and they like working things out and some clinicians don't, so I think a bit of a blurb on what they show"- Psychologist 1*

Technical skills varied greatly between HCP participants. This is a potential challenge for the utility of the BigO clinical portal or similar systems in clinical settings. On the other hand, participants felt that the majority of HCPs would be willing to engage with such technology to help as many children as possible and to understand the overall behavior of patients living in their respective environments.

3.6.3. Recommendations to improve functions on the BigO clinical portal

It was recommended that there should be an option to communicate with patients and other HCPs. This would include creating goals and providing feedback to patients.

It was also recommended that the BigO clinical portal should link with other hospital-based data such as biochemistry results. This would be useful information for dietitians, as patients may have childhood obesity in addition to being malnourished.

3.6.4. Recommendations to Improve Graphs Available on the BigO Portal

There were multiple recommendations for the graphs available on the BigO clinical portal. This included the activity graphs and heatmaps available on the BigO clinical portal. It became evident that many of the graphs were not self-explanatory to the participants. Further suggestions included increased clarity for the information presented, including units of measurement of amount and intensity of physical activity and having the option to group patient data as this "*would be useful for comparing a group of children with childhood obesity pre and post treatment phases*".

4. Discussion

4.1. User testing and feedback from children and adolescents

The purpose of this research was to test engagement and technical usability of the myBigO app, gather views from participants on key factors that facilitate and hamper use and identify recommendations for app improvement. No major usability barriers for the myBigO app were identified among young people. One of the main engagement barriers according to young people was the perceived negative judgement peers would make of such a health-related app. The next version of myBigO app could consult end users with regard to gamification or other appealing technology to address negative perceptions.

Participants completed tasks within the expected two-to-three times the amount of time taken by an expert user [31]. Technical usability testing also revealed the following technical barriers for app use: notifications of battery optimisation, inappropriate language for image annotations which researchers may assume are obvious and lack of app compatibility with certain phone models. These barriers could have added to participant time for completion of Tasks 2 and 3. Recommendations for changes to future iterations of the app included compatibility with more phone models, incorporating reminders, including more detail and age-appropriate language for annotating image data and a food diary/gallery. It is clear that the current myBigO app worked as a prototype and that future versions should run on every smartphone and smartwatch. Porting the app code to other smart devices is very straightforward so future developments will be feasible.

4.2. User testing and feedback for clinical portal among HCPs

Overall, the BigO clinical portal was perceived to be potentially beneficial for clinical practice in Ireland because it included objective dietary and physical activity data that are important for treatment planning in children and adolescents with obesity. However, further development was suggested regarding the validity and reliability of the information visualised on the portal. The key issue identified was that behavioural data should be presented in a clear and self-explanatory way for HCPs working in clinical settings who may not use research-

based software regularly in their workday. In order to interpret information correctly, graphs and maps required clear and explanatory legends, and photographs should be large enough to view.

In this study, four of the technical usability tasks took HCPs greater than three times that of an expert to complete. Following on from this study, further research and development is required to improve the functionalities that the BigO system offers to HCPs. Continued work is required to evaluate the usability of the clinical portal among HCPs based in other countries and to determine the training that is required for novice users. This is highly valuable feedback for developers and can be easily implemented in the subsequent versions of the system.

4.3. Comparison with prior work

The use of digital health with pediatric populations is a rapidly evolving area which the COVID-19 pandemic accelerated. Studies have shown that families are open to telehealth, with high levels of satisfaction among those who have tried it [36]. Moreover, a recent scoping review of mHealth for pediatric weight management found that while the use of mobile devices is an emerging research area among this clinical population, few studies have formally assessed technical usability [37]. In the 'PEGASO' project, 74 adolescents between the age range of 13 to 16 years from Spain, Italy, and the United Kingdom participated in co-designing and feasibility testing a mHealth intervention for healthy weight promoting behaviors [38]. Some findings that are similar to ours include that the adolescents favored the use of age-appropriate and easily comprehendible language, notifications and self-monitoring features in mHealth technology [38]. The authors also provided further insight from adolescent participants that could prove valuable for developing and enhancing interaction of mHealth technologies for healthy eating and physical activity behaviors in youth [38].

The perception of adolescent participants that their captured images were being monitored by their healthcare professionals was inaccurate even though this was explained to participants during the recruitment process. This sense of clinical monitoring was also observed in another study [39] and highlights the importance of ensuring that participants understand that submitting images would not result in feedback from pediatric health professionals. It highlights the contrast between the preferences of the patient and that of the HCPs (who reported valuing the monitoring option) and the requirement for clear, congruent information and training on both sides of the clinical relationship.

The considerations for battery optimisation have been identified by BigO researchers as factors that might limit engagement and data collection. These negative app experiences were addressed in the software and reported elsewhere [26]. BigO researchers also reported that many retailers of popular smartphones have created unique, specialised and non-documented processes that inhibit apps working in the background and which require individualised step-by-step guidelines for using myBigO app on such smartphones. However, with recent advances in mobile processors and battery life this has been reconsidered in current versions of mobile operating systems. Therefore running apps in the background should not pose such a barrier in the future.

The technical skills of some HCPs in this study may be a potential barrier for the implementation of the BigO clinical portal in clinical settings, which has been previously highlighted with HCPs elsewhere [36]. Similarly, in Ireland, a study was conducted based on factors that affect the use of Electronic Patient Records (EPR) amongst general practitioners (GPs) [40]. The perceived barriers included insufficient training and the absence of the computer skills required to complete different tasks. It was suggested that better training and financial support may reduce the barriers related to the use of EPR in clinical practice [40]. Providing adequate training for HCPs working with the BigO clinical portal will be essential for implementation in clinical practice. Training should go beyond the operation of data systems; it should support advocacy for HCPs and patients [41]. There is a dearth of evidence regarding the amount and type of training needed by HCPs for the successful introduction and sustained use of novel digital technologies like clinical portal systems in practice.

Many mHealth apps targeting youth exist but few are evidence-based or tested with end-users for their usability and acceptability; especially young individuals with obesity, who are a vulnerable group in research [7,42]. Most interventions have been designed and trialled in adults, or for various other health conditions in youth [19,43–48,42] and the majority of mHealth interventions in the literature are limited to feasibility and pilot studies [49]. The lengthy research process of testing and validating apps for health interventions, compared to the rapid speed that technology develops, could be a contributing factor to the current lack of research and use of technology in clinical or preventative interventions for young people with obesity [16]. By the time an app undergoes extensive research and development to be implemented for health, it may be outdated and less appealing to young people who are potentially more interested in the latest designs and features of novel commercial apps [16].

Although the young participants in this study report that the BigO app was user-friendly as a self-monitoring tool, our overall results show that additional development might enhance regular usage in clinical participants engaged in obesity treatment. Previous studies highlighted many challenges in accurate reporting of food intake in children and adolescents including apathy, lack of motivation and reduced cooperation compared to others at different developmental stages [50–52]. The novel role of technology and its potential to enhance the accuracy of dietary information from adolescents is also documented in literature [52,53]. High acceptability has been reported for a combined approach of recording dietary information using both technology and more traditional pen and paper records in young people (aged 8–18 years) with and without disabilities [54]. Notably, this provides valuable insight as rates of obesity are higher amongst youth with disabilities [55].

4.3.1. Limitations

Although small group sizes are recommended for focus group sessions [56], four participants is lower than ideal 6–12 and small sample size is a limitation of the current study. We attempted to reduce this in the first instance, by inviting all eligible children and young people in obesity treatment to join the BigO study, all of whom (n = 37) were subsequently invited to take part in this study. Those who did participate may have been more willing and engaged users, which we acknowledge can introduce selection bias. Future research could purposively sample participants with differing levels of app engagement to explore experiences among diverse user types. We did not collect data on the smartphone user characteristics of the sample and this could be incorporated into future work to define the sample in more detail.

Members of the research team who conducted and analyzed data from the focus groups had backgrounds in nutrition, dietetics, physiotherapy, mHealth, eHealth, pediatric obesity and pediatric healthcare. Although this positively contributed to many aspects of the study in terms of knowledge of the user and healthcare/clinical issues, it also adds to the risks of researcher biase. The team incorporated measures in the research design to limit potentially negative biases. Measures

included research team members documenting observation notes for the duration of the study, scheduling regular meetings amongst the research team throughout method planning, study implementation, analysis and write up to optimize collaboration. In turn, altering the environment the focus group was conducted in and scheduling the focus group outside usual clinical hours ensured a calm but familiar space conducive to facilitating thoughts and discussion. Such procedures can assist in reducing personal, methodological, interpersonal and contextual influences [57].

Furthermore, one of the HCP participants and the clinical researcher participant are also authors of this work, which was necessary due to the limited number of individuals in Ireland with clinical pediatric obesity experience. HCPs were based in one clinical setting (a National treatment center), and while the findings may not translate to all pediatric obesity treatment services, the participating HCPs were experienced in specialist multi-disciplinary treatment of pediatric obesity and their relevant experience improves the value of the data. While both samples were small, the rigorous methods presented in this paper were successfully implemented and feasible in a clinical setting, and therefore could be adapted to evaluate other mHealth services and tools.

Testing was conducted with adolescents in a clinical setting and not in the participants 'real world' in which they would usually use the app. This could have resulted in responses that were different to the 'norm'. A drawback of the 'think aloud' method is that it may have been challenging for participants to perform the task and share their thoughts out loud simultaneously, which could have added to task completion time. However, it did enable the testing process to be as intuitive as possible and revealed specific challenges that users faced.

Finally, though multiple BigO sites recruited children in Europe, the majority were from a school population and not a clinical population. In another BigO site in Greece, a clinical group of children with overweight and obesity were also recruited to the main BigO study, however technical usability testing was not conducted through Greek due to resource limitations. The focus of our current study was to establish technical usability in a clinical end-user group for whom the BigO system might be a useful adjunct to treatment. While our study provides formative data, future studies should assess multiple clinical sites to assess generalizability and to confirm technical usability in other clinical populations around Europe.

4.3.2. Strengths

A major strength of this study was engaging clinical end-users to test the app and clinical portal. Studies specifically testing usability and engagement of mHealth apps in adolescent obesity treatment are limited [42]. Numerous challenges in conducting research and particularly clinical research during the Covid-19 pandemic have been highlighted [58]. The 'citizen scientist' methods employed in this study represent advantageous approaches to conducting research with youth and capturing their social and environmental exposures during a time of societal upheaval with pandemic lockdowns. Furthermore, the rich data collected during pandemic lockdowns using such apps provide important opportunities to compare behavioural data before, during and after such global emergencies. This could be beneficial to consider as part of preparatory work for future emergency situations.

While this study did not evaluate health outcomes of pediatric obesity treatment, previous BigO Study research demonstrated that children in treatment for obesity considered the BigO app and smartwatch as acceptable and easy to use in practice [59]. The methodology devised and evaluated in this study can be replicated to strengthen the evidence base for the potential of using the BigO system to explore relationships between local environments and health behaviours among young people. Capturing large quantities of data using the BigO system is valuable for informing the design/planning of environments and public policy interventions aimed to reduce exposure to food advertising and support healthy living in high-risk populations [60]. Essentially, this will contribute to the overall aim of the BigO study by advancing the current evidence base on the impact of these factors on childhood obesity in Europe [24].

The usability testing of the clinical portal system among HCPs was critical to the implementation and successful use of such digital health tools in clinical practice [61]. Mixed methods used in this study included technical usability tasks and interviews to explore benefits and challenges of the BigO clinical portal. The HCP participants were working in a EASO centre of excellence for pediatric obesity treatment which facilitated gathering information and knowledge from highly specialised key clinical end-users who were keenly aware of the complexities of obesity treatment [7].

4.4. Implications for research and practice

This study highlights the challenges in recruiting children and adolescents with obesity for mHealth research and the need for strategies to improve engagement with this vulnerable population who could benefit from access to novel and safe adjuncts to treatment. Acknowledging the burden of attending treatment for children and young people, this study demonstrated that additional asks such as research participation yielded a low recruitment rate, and oversampling is likely required.

At an organisational level, the focus group findings suggested that the 'citizen scientist' element of the BigO study increased awareness of the frequency, content and influence of food marketing. The rationale for involving children as 'citizen scientists' is rooted in the view that researchers do not have access to the social and environmental exposures that influence young people's behaviours. From a public policy position, measuring exposure to advertisements through use of the BigO system could be used to highlight the role of the environment and how policy decisions support or obstruct healthy behaviors. Food marketing is disseminated widely on digital platforms and the unregulated and targeted marketing to children exploits their vulnerability [62-64]. Though the BigO system facilitates measurement of exposure to ads in the child's offline environment, additional development to include measurement of the digital environment would be useful.

5. Conclusions

This mixed methods study provided valuable formative findings from clinical end-users indicating that the myBigO app is likely to have sufficient technical usability in clinical participants, and that it may be a helpful adjunct to treatment. Participants suggested several reasons for lower-than-expected engagement levels and ways to enhance future iterations of the system.

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CRediT authorship contribution statement

Niamh Arthurs: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Sarah Browne:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Rebekah Boardman:** Writing – review & editing, Methodology, Formal analysis, Data curation, Conceptualization. **Shane O'Donnell:** Writing – review & editing. **Gerardine Doyle:** Writing – review & editing. **Tahar Kechadi:** Writing – review & editing, Software. **Arsalan Shahid:** Writing – review & editing, Software. **Louise Tully:** Writing – review & editing. **Grace O'Malley:** Writing – review & editing, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

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Institutional review board statement

The research protocol was reviewed by the hospital research ethics committee at Children's Health Ireland at Temple Street, Dublin and approved (18.013) as part of the BigO study.

Informed consent statement

Informed consent was obtained from all participants involved in the study.

Appendix A

Steps for getting started with data collection in the BigO study.

1) The first step for all participants is to complete and sign the consent and assent forms along with their parents/guardians.
2) All the participants in the BigO study are required to install the mobile application. The mobile application can be downloaded from Google PlayStore or Apple App Store by searching for the name 'myBigO'. There are also further details and instructions on the app at the following link: https://bigoprogram.eu/mybigo-app/
3) Once the BigO research team receives the signed consent forms and the participants install the 'myBigO' app, unique registration codes are shared with the participants to start interacting and using the 'myBigO' app.
4) The participants are asked to upload pictures of their meals, drinks and food advertisements daily for at least a period of four weeks. Specifically, the participants are asked to:

I. Every day use the myBigO App to take these photos:

- At least 1 photo of a meal –e.g. breakfast, lunch, or dinner
- At least 1 photo of a snack
- At least 1 photograph of a drink you have

I. Every day use the MyBigO App to take photographs of food or drink advertisements in your local area. Examples of places where foods/drinks are advertised include:

- Bus stops, bus/train stations or on buses
- Outside/inside shops, take-aways or other food outlets
- Billboards
- A flyer or brochure
- A poster or banner inside or outside a venue

5) At the end of the BigO data collection study, participants will receive certificates of participation along with medals. The medals awarded are based on the participants' interaction with 'myBigO' app and the engagement status that they receive on the app. These statuses include bronze, silver, and gold. The participants who are consistent in uploading data related to food, drinks and food advertisements receive a gold status and hence a representative gold medal.

Appendix B

Study questionnaire for adolescent participants*

Name: _____
Gender: Boy ☐ Girl ☐
DOB: _____
School:_____Year:_____

Level of Experience with smartphones:
Do you have your own mobile phone? YES ☐ No ☐
What make and model is this?
_____
Who is your mobile phone service provider? O2 ☐ Vodafone ☐ 3 ☐ Lycamobile ☐
Tesco Mobile ☐ Other ☐ (Please specify)_____

For how many years have you been using smartphone applications?
_____
What phone did you use for the BigO study? My own phone ☐ Parents phone ☐
Siblings phone ☐ Other ☐ (Please specify) _____
If not your phone, what was the make and model of the phone you used for the BigO study?
_____

Did you wear a smartwatch as part of the BigO study? YES ☐ No ☐
Phone used for BigO study:
How often do you use apps? Every: 5minutes ☐ 15minutes ☐ 30minutes ☐ 45minutes☐ Hourly ☐
Daily ☐ Weekly ☐ Monthly ☐
Do you have Internet access at home? YES ☐ No ☐
Do you have access to the Internet on your phone? YES ☐ No ☐
What type of access do you have at home? Wi-Fi ☐ Wired access ☐ 3G ☐
Other_____
Is internet access on your phone limited? Monthly data plan ☐ No data plan ☐ Unlimited data ☐
Other_____
Did you notice an increase in your data use while using myBigO app?

YES☐ No☐

How do you mainly access internet at home? Mobile phone☐ Laptop☐ Desktop computer ☐ Tablet ☐

Other_____

Tasks to complete:
TASK 1:
Re-do the questionnaire

(*continued on next page*)

(*continued*)

TASK 2:
Show the researcher how you use myBigO app functions:

- Taking food/beverage photos
- Taking food ad photos

TASK 3:
At the food table take one photo of each of the following using myBigO app and submit it:

- A bowl of breakfast cereal
- A sandwich as a lunch meal
- A dinner meal
- A cup of tea
- A food ad

TASK 4: Please complete the following questions about using myBigO app in everyday life. Name 3 things that you think could be improved about myBigO app:

1._____
_____
_____

2._____
_____
_____

3._____
_____
_____

Name 3 things about myBigO app that you liked:

1._____
_____
_____

2._____
_____
_____

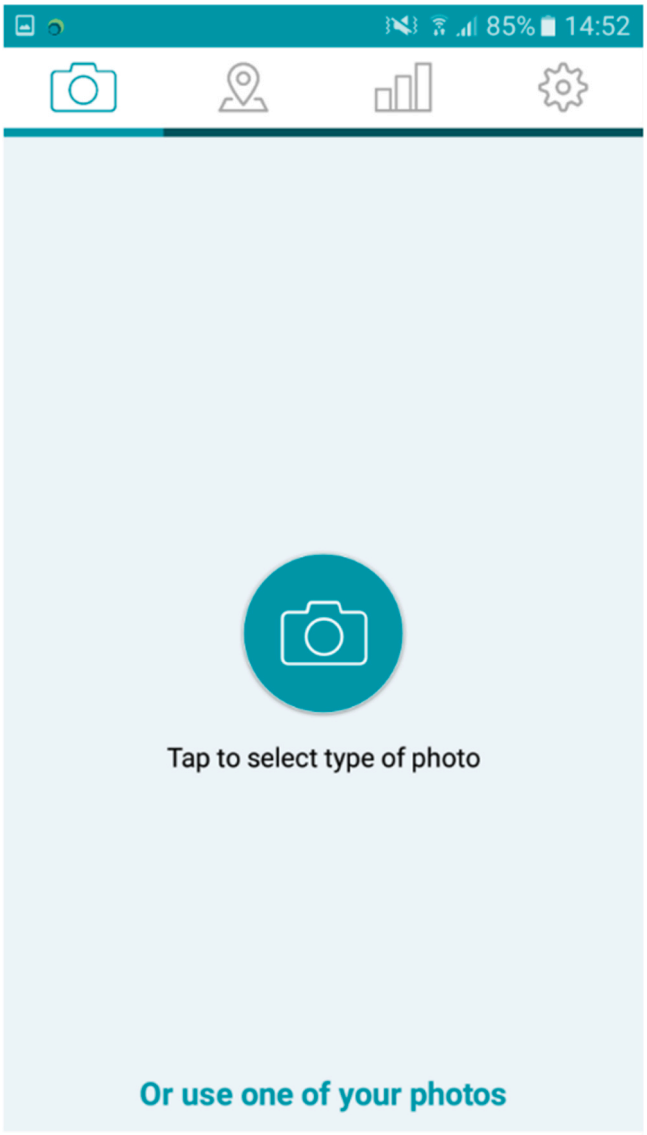
3._____
_____

*Technical usability testing booklet for adolescent participants (Arthurs et al. 2021)

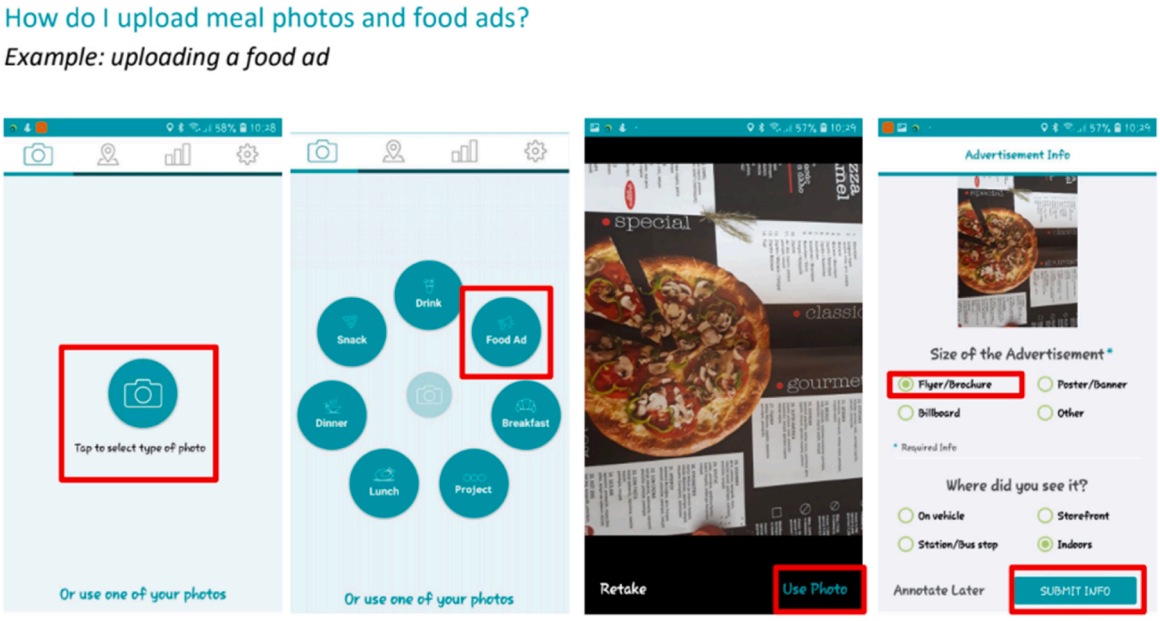
Appendix C

Screen shots of tasks using myBigO app during usability testing.
TASK 1: Screenshot of questionnaire which participants completed following registering and downloading myBigO app

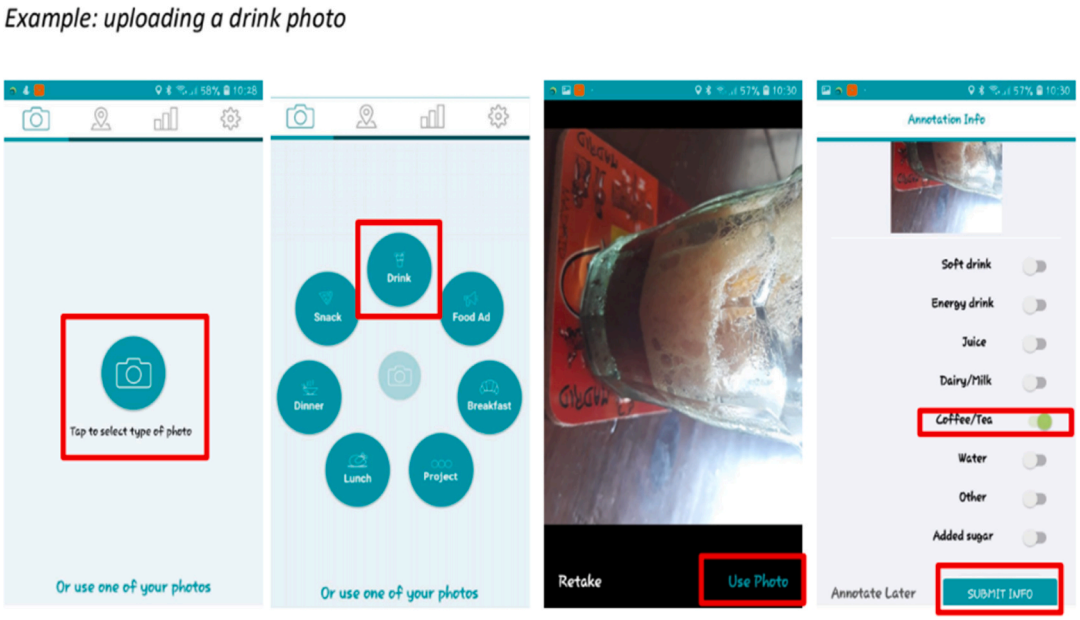
TASK 2: Screenshot of how to use myBigO app to take food/beverage photos and food ad photos, which participants were asked to describe



TASK 3: Screenshot illustrating the steps from taking a meal, drink or food ad photo, answering the annotations and submitting the information.
1000



1001



Appendix D

Focus group questions with adolescent participants*.

Thank you for taking part in this focus group discussion. The discussion will last about 30 min. We will audio-record the session so that we don't miss anything you say. The recording will be written down later without your names added, and then the recording will be deleted. No personal or identifying information about you will appear in any reports from the research.

We are going to talk about how you found using the myBigO app in your everyday life. The purpose is for us to understand all the things that were easy, difficult, annoying, clever, good, and bad about the app. Please be totally honest as there is no right or wrong answers. Your opinions are very important to us.

Questions for myBigO app group.

1. Overall what did you think about using the myBigO app at home?
2. What was good about using the myBigO app?

3. What made it difficult to use the myBigO app?
4. How did you find the training that was provided for using the myBigO app?
5. Following the training, did you understand why we wanted you to take pictures of food ads?
6. What is your understanding of what we are going to do with the images you captured?
7. What motivated you to take pictures of your food/beverages/meals/snacks using the app?
8. What motivated you to take pictures of food ads in your neighbourhood using the app?
9. For what reasons did you not take photos of your food/beverages/meals/snacks using the app?
10. For what reasons did you not take photos of food ads using the app?
11. Do you have any thoughts/issues about using your own data for the app?
12. Do you think myBigO is a useful tool for children who are overweight?
13. What kind of reaction did your family and friends have to the myBigO app?
14. Would you recommend the myBigO app to a friend and why/why not?
15. What changes, if any, would you suggest for myBigO app and the study?

***Focus group questions with adolescent participants (Arthurs et al., 2024).**

Appendix E

*Demonstration of the BigO clinical portal to HCPs**

The demonstration focused on a step-by-step guide on the different features of the BigO clinical portal. This included [1]: logging onto the BigO clinical portal using Google Chrome at the following link: https://gateway.mysphera.com/#/login, [2] creating a new patient profile such as inputting the age and gender of the patient, entering anthropometric measurements such as weight and height of a patient, [3] discussing what the different icons represent on the portal such as bronze, gold and silver medals, [4] viewing data that has been submitted by a patient such as pictures of the food that has been entered (breakfast, lunch and dinner), [5] looking at the completed questionnaires that have been completed by patients, [6] physical activity that patients completed, [7] viewing the data that has been entered from different countries such as Ireland or Greece and [8] logging out of the BigO clinical portal.

*Demonstration of the BigO clinical portal **to health and research professionals (Arthurs et al., 2024).**

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