Can brief, daily training using a mobile applications help change maladaptive beliefs? A cross-over randomized-control study evaluating the efficacy of a mobile-app based intervention in reducing maladaptive beliefs and obsessive-compulsive symptoms.

Abstract

Background: Obsessive compulsive disorder (OCD) is a disabling condition with a wide variety of clinical presentations including contamination fears, fear of harm and relationship-related obsessions. Cognitive behavioral models of OCD propose obsessive-compulsive (OC) symptoms result from catastrophic misinterpretations of commonly occurring intrusive experiences and associated dysfunctional strategies used to manage them. OCD-related maladaptive beliefs including inflated responsibility, importance and control of thoughts, perfectionism and intolerance for uncertainty increase the likelihood of such misinterpretations.

Objective: Consistent with accumulating evidence suggesting mobile health (mHealth) apps based on cognitive-behavioral principles may lead to significant reductions in psychopathological symptom, we assessed the effectiveness of a novel cognitive training app (GGRO) designed to challenge OCD-related beliefs.

Methods: Ninety-seven students were randomized to immediate use (iApp) or delayed use (dApp) groups of GGRO. All participants were requested to complete web-based assessment, with questionnaires relating to maladaptive beliefs, mood and OC symptoms at baseline (T1), 15 days following baseline (T2) and 30 days following baseline (T3). Participants in iApp group started using the app at baseline and continued using the app for 15 consecutive days. They were then requested to stop using the app until T3. Participants in the dApp group were requested to wait for 15 days and only then start using the app (cross-over) for 15 consecutive days.

Results: All participants used the app for a mean 14.07 (*SD*=1.41) days with a 2.94 levels per day. Replicating previous findings, app use was associated with medium-large effect size reductions in both groups iApp (n=51) and dApp (n=46). In the iApp group, all effects remained significant during 15 days follow-up. Analyses focusing on

the first two assessment occasions revealed significant Treatment $\times$ Repeated Measures interactions on maladaptive beliefs, several OC symptom measures and self-esteem.

Conclusions: This study provides further evidence for the efficacy of GGRO as a mobile delivered training exercises useful for the reduction of OCD-related beliefs and symptoms. **Trial registration**: ClinicalTrial.gov ID NCT03571464.

Introduction

Obsessive-Compulsive Disorder (OCD) is a disabling disorder that causes impairment in multiple areas of patients' lives [1,2]. OCD is characterized by the presence of repetitive unwanted and disturbing intrusive thoughts, images or urges (obsessions), and/or ritualistic and repetitive acts (compulsions) [3]. The content of OCD is heterogenic, comprising themes as scrupulosity [4], repugnant obsessions [5], moral and physical contamination fears [6], cleaning compulsions, obsessional doubts and relationship-related obsessions [7].

Cognitive-Behavioral Therapy (CBT) combined with exposure and ritual prevention is the first choice psychological treatment recognized by the National Institute for Clinical Excellence (NICE) [8]. CBT models of OCD postulate that catastrophic misinterpretation of intrusive thoughts, images and urges, and the use of counterproductive cognitive and behavioural strategies to manage them lead to their escalation into chronic obsessions [9–11]. A number of maladaptive beliefs have been found to be associated with this catastrophic misinterpretation: inflated responsibility, over-importance of thoughts, desire to control one's thoughts, overestimation of threat, need for certainty and perfectionism [12,13].

Many individuals, however, have great difficulties in accessing CBT therapy, either because of their high cost, the stigma associated with treatment, or the lack of available trained professionals [14,15]. Information and Communication Technologies (ICTs) including mobile apps and Internet based interventions have been suggested to increase accessibility and availability of CBT-based interventions [16–18]. Such alternative CBT delivery systems are consistent with the stepped-care approach for OCD [8]. Clients with OCD may begin with low intensity interventions (e.g., self-help materials) and, if needed, gradually receive more intense and expert interventions [19].

ICTs have been implemented significantly less in the treatment or prevention of OCD symptoms than in other mental disorders. Most studies assessed the efficacy of video-conference or telephone therapy, as applied in exposure and response prevention component [20–22]. In addition, most existing CBT-based mobile applications translate Internet-delivered desktop treatment programs into mobile apps without exploiting the special advantages of the mobile app platform. These programs often have a long duration (e.g., more than 20 min per interaction) and involve tasks requiring high internal motivation, a long attention span, and high persistence from users (e.g., enter a significant amount of free text [23].

Recently, an exploratory study evaluated a brief, game-like, training exercise for challenging OCD-beliefs delivered via a mobile application platform named "GGRO – GG relationship doubt and obsessions V1.1" [24]. GGRO is one of various mobile applications designed by GGApps to challenge beliefs associated with a range of psychological difficulties (e.g., depression, body image distress, low self-esteem). GGRO was specifically designed to challenge maladaptive beliefs that underlie common OCD symptoms (e.g., contamination, repugnant thoughts) as well as relationships obsessions (e.g., obsessive preoccupations regarding the suitability of the relationship or the relationship partners) [7,12,25]. The platform was designed to help users learn to respond to statements that challenge OCD-related beliefs by embracing them (i.e., pulling them down towards themselves) and by rejecting statements that are consistent with beliefs underlying OCD symptoms and low self-esteem (i.e., throwing them upwards, away from themselves; see Method section). Following CBT principles, statements challenging OCD-related beliefs include alternative, more adaptive interpretations of thoughts, emotions and events as well as statements encouraging approach behavioral strategies (e.g., tolerance of negative feelings and acceptance of

thoughts). Increasing accessibility to such statements is expected to reduce adherence to OCD-related beliefs and associated symptoms.

The results of this study, carried out with twenty participants from non-clinical population, suggested that training 3 minutes a day for a period of 15 days was associated with a significant, large effect-size reductions in levels of OCD-related beliefs measured by the Obsessive Beliefs Questionnaire-short form [24]. Participants also showed significant pre-post training decreases in levels of OCD symptoms, measured by the Obsessive-Compulsive Inventory [26], including relationship-related OCD symptoms measured using the Relationship Obsessive-Compulsive Inventory [ROCI; 27] and the Partner-Related Obsessive-Compulsive Symptoms Inventory [28]. Moreover, pre-post changes in levels of OCD-beliefs were associated with reduction in OCD symptoms levels.

The aim of the present study was to further evaluate the efficacy of GGRO reducing OCD related maladaptive beliefs and OCD symptoms. Specifically, a randomized controlled trial with crossover design was carried out in non-clinical student population to assess pre-post changes in levels of OCD-related maladaptive beliefs and OCD symptoms, including relationship OCD (ROCD) symptoms, self-esteem, and depressive symptoms following 15 days of using GGRO. Our main hypothesis was that students using GGRO immediately following baseline assessment (iApp) would exhibit greater declines in obsessive compulsive related beliefs than would students that did not use GGRO at this phase of the study (dApp; see Figure 1). Consistent with previous research showing association between OCD symptoms and self-esteem [29,30], we expected a decrease in OCD, ROCD symptoms and an increase in self-esteem in students allocated to the iApp group relative to the students in the dApp wait control group. Following cross-over (T2), we expected that user gains in the iApp group would

be maintained at T3. At this phase, we anticipated that students starting to use GGRO (dApp group) would show statistically significant reductions in OCD-related maladaptive beliefs and symptoms and an increase in self-esteem from T2 to T3 assessments. Consistent with a previous study using GGRO in a student population [24], we did not expect a significant reduction in depression symptoms.

Method

Participants. Participants were recruited from the University of Valencia during the first semester of the 2016/2017 course from nine classes at the Psychology Faculty. The students were invited to voluntarily participate in a study about beliefs, self-talk, mood and relationships. Participants interested in participating were informed of their rights and provided online informed consent in accordance with university IRB standards. The study received the approval of the University of Valencia ethics committee (H-1488382719361). Inclusion criteria included native level Spanish, having experienced at least one stable romantic relationship and having a mobile device capable of installing GGRO (available for download via Google Play or the App Store).

Consistent with common practice in OCD related research, the sample used in the present study comprised of non-clinical participants [31]. Like individuals who are clinically diagnosed with OCD, non-clinical participants tend to engage in compulsive behaviors to alleviate distress [32]. Furthermore, taxometric studies of OCD [33] have found that OCD symptoms and OC-related beliefs are best conceptualized as continuous dimensional rather than categorical.
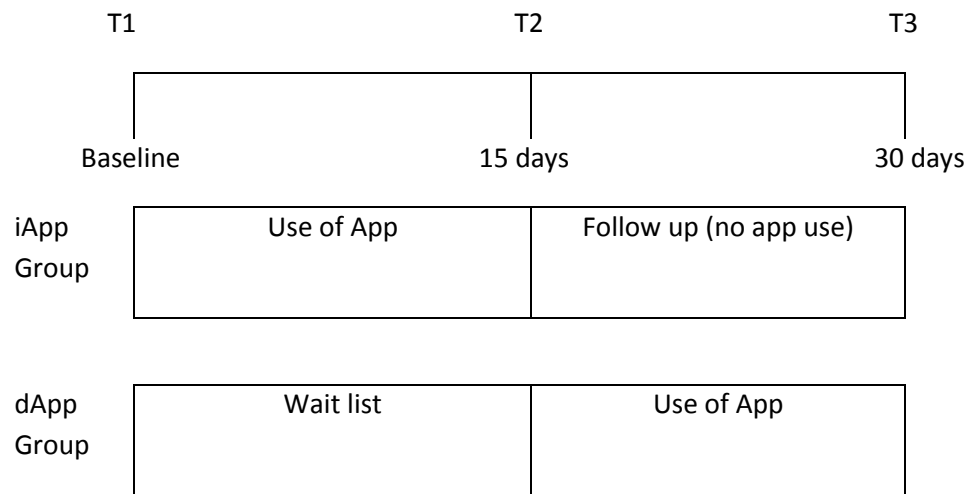
All participants volunteered and were included a draw for a prize of a dinner for two (valued in 30€). Ninety-eight students attended a recruitment seminar in which they were explained the general procedure of the research. They were then asked to download that application, and completed the pre-treatment evaluation (Time 1) on

Qualtrics -a secure online survey platform. Emails with the corresponding survey links were sent to participants at Time 2 and Time 3. From the 98 students who wanted to take part in the study, one was excluded because he did not have a stable partner in the present or in the past. The final ninety-seven participants (79 women, 81.4%) were second and third year students at the BA program, with ages ranging from 18 to 65 years old ($M = 21.56$; $SD = 7.07$). The majority (61.9%) reported medium socioeconomic status (28.9% below average, 9.3% above average). More than half of participants (56.3%) were in a romantic relationship at the time of the study (median length of 33 months).

Study design

The study was a randomized controlled trial with crossover design (see Figure 1). The intervention was a mobile delivered cognitive training using GGRO. Participants were randomized to an App first group (iApp, $n= 51$) or a wait list crossover group (dApp, $n= 46$). Participants in the iApp group started using the app immediately (T1) for a period of 15 consecutive days (until T2). They were then requested to stop using the app until the end of the trial. Participants randomized to dApp group, were requested to start using the app at T2 (15 days after the iApp group). They were than requested to use the app (crossover) for the subsequent 15 days. In both groups, participants were instructed to complete 3 levels a day (approximate 3min a day). The CONSORT EHEALTH checklist is presented as Multimedia appendix 1.

Figure 1. Study design with both groups

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        T1                          T2                          T3
        ┌───────────────────────────┬───────────────────────────┐
        │                           │                           │
     Baseline                    15 days                     30 days

iApp    ┌───────────────────────────┬───────────────────────────┐
Group   │        Use of App         │   Follow up (no app use)  │
        │                           │                           │
        └───────────────────────────┴───────────────────────────┘


dApp    ┌───────────────────────────┬───────────────────────────┐
Group   │        Wait list          │         Use of App        │
        │                           │                           │
        └───────────────────────────┴───────────────────────────┘
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Randomization

Randomization was carried out on a 1:1 ratio and based on a prespecified computer-generated randomization list [34]. Group assignment was performed onsite using the next available number on the randomization list.

Intervention

GGRO was developed by the last author (GD) an expert in OCD and related disorders in collaboration with GI a mobile platform developer. This application consists of training exercises that are intended to help people increase accessibility to functional self-statements that facilitate adaptive interpretations for thoughts, emotions and events associated with OCD (see Figure 2). Users are presented with 'blocks' featuring statements such as "I take things as they come" or "Everything can end in a catastrophe". Users then have to respond to these statements by either embracing them (i.e., pulling the 'blocks' downwards towards themselves) or rejecting them (i.e., throwing the 'blocks' upwards away from themselves).

Users progressively complete 45 levels dedicated to OCD relevant maladaptive beliefs (3 levels per belief) such as dealing with threat, importance of thoughts,

overcoming perfectionism, etc. In this way, the user is exposed to alternative interpretations of the relevant maladaptive belief in each stage, increasing accessibility to functional self-statements encouraging adaptive interpretations for thoughts, emotions and events (e.g., the occurrence of distressing doubts) associated with OCD. For instance, statements challenging perfectionism may include "Mistakes teach me to overcome my fears" and "Imperfect is human". Users are also encouraged to adopt approach behavioral strategies (rather than avoidance) including tolerance of negative emotions by responding to statements such as "I can tolerate doubts".

Following the completion of each level the user receives feedback depending on the length of time it took them to complete the level (*0* to 3 stars). A short memory evaluation screen (i.e., memory boost) follows this feedback. In this screen, three statements are presented to the user. The user has to recall which of the statements appeared in the level just completed. The correct response results in a "Correct!" message and an incorrect response is followed by "You'll get it next time" feedback message. The two types of feedback increase attention to the training and encourage engagement.

The user is then passed on to the next level. Three levels address a specific maladaptive belief. Before dealing with a new belief, a screen is presented with the rational for challenging the specific maladaptive belief. For example, before learning to challenge over-estimation of threat, users are presented the following statement: "The world can be dangerous, but the tendency to look for danger all the time increases fears and anxieties. Let's learn to reduce this tendency!". Following the completion of six levels pertaining to two beliefs (e.g., importance of thoughts and overestimation of threat) users may see an encouraging statement such as: "Excellent! Now you've learned how to better deal with your thoughts and to better recognize the way you over-

estimate threat". Push notifications remind users to use the app each day. Following the completion of 3-levels at a given day, a screen prompting users to stop using the app for that day appears. Users are also advised to train once a day at a preset time rather than in response to distressing thoughts or events. GGRO requires mobile device with an operating system iOS 7 or above and android 4.2 (or above).

Figure 2. GGRO Screenshots.
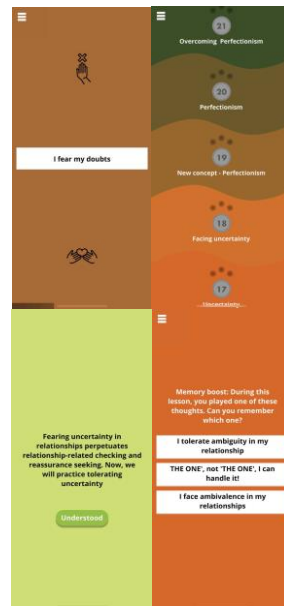
Measures

The Obsessive-Compulsive Inventory (OCI-R) [26,27] The OCI-R is a self-report composed by 18-item with a 5-point likert scale ranging from 0 (*not at all*) to 4 (*extremely*), which assess OCD symptoms. The OCI-R possesses good internal consistency for the total score (alphas ranging from .81 to .93 across samples) [26], In our study, the internal consistency for the total scale was .84 at T1, .83 at T2, and .83 at T3.

The short form of the Obsessive Beliefs Questionnaire (OBQ-20) [12] is the abbreviated version of the 44-item Obsessive Beliefs Questionnaire-Revised [12]. The OBQ-20 is a self-report assessing pan-situational cognitions associated with OCD. It is

composed by 20-item on a 7-point scale ranging from 1 (*disagree very much*) to 7 (*agree very much*). The OBQ-20 has shown satisfactory psychometric properties [36,37]. The internal consistency of the scale as a whole in our sample (Cronbach's alpha) .88 at T1, .93 at T2, and .94 at T3.

The Relationship Obsessive–Compulsive Inventory – short version (ROCI-S). The ROCI-S is a shortened version of the relationship obsessive-compulsive inventory (ROCI) [28], a 12-item measure assessing three dimensions of relationship-centered ROCD symptoms: love for the partner, the "rightness" of the relationship and the partner's love for oneself. The ROCI-S consists of 6-item with 2 items assessing each of the three relationship –centered ROCD dimensions (the 2 items showing the highest average loading on the two original ROCI validation studies) [28]. In an independent sample (n=714; 302 females; Mean age =38.73; SD=12.65), the mean of these six items (ROCI-S total score) showed good reliability (Cronbach α = .85) and correlated very highly (r=.97) with the total ROCI total scores. In the current study the internal consistency (Cronbach's alpha) of the mean of all ROCI items was .80 at T1, .83 at T2, and .79 at T3.

The Partner-Related Obsessive–Compulsive Symptoms Inventory – Six-item version (PROCSI-Si)[29] is an abbreviated version of the partner-related obsessive compulsive inventory (PROCSI) [38], a 24 item measure assessing partner-focused ROCD symptoms. The PROCSI-Si consists of 6 items. The items selected showed the highest correlation of single item with relevant subscale in one half of a randomly split sample (n=356; 151 females; Mean age =38.58; SD=12.55). The mean of these six items (PROCSI-Si total score) showed good reliability (Cronbach α=.90) and correlated very highly (r=.98) with the total PROCSI total scores in this sample. The PROCSI-Si total score also showed good reliability scores (Cronbach α=.92) and correlated highly

(r=.98) with the PROCSI total scores in the independent half of the sample (n=356; 151 females; Mean age=38.88; SD=12.79). The internal consistency of PROCSI-Si (Cronbach's alpha) in the current sample was .78 at T1, .83 at T2, and .77 at T3.

The short version of the Depression, Anxiety, Stress Scale (DASS) [39–42]. The DASS is a self-report questionnaire that evaluates negative emotional symptoms (depression, anxiety and stress). The short version consists of a 21-items on a 4-point scale ranging from 0 (*did not apply to me at all*) to 3 (*applied to me very much, or most of the time*). In the present study only depression scale (7 items) has been used. The DASS scales have been shown to have high internal consistency [42]. The internal consistency of Depression scale (Cronbach's alpha) in the current sample was .90 at T1, .90 at T2, and .91 at T3.

The Single-Item Self-Esteem Scale (SISE) [43]. The SISE is a self-report measure which asks participants the extent to which the sentence "I have a high self-esteem" describes them on a 9-point scale ranging from 1 (*not very true for me*) to 9 (*very true for me*). The SISE has been found to have high test-retest reliability, criterion validity coefficients above .80 (*Mdn* = .93 after correcting for unreliability) with the Rosenberg Self-Esteem Scale (RSE), and a similar pattern of construct validity coefficients as the RSE with 35 different constructs [43]. Using longitudinal data, Robins et al. [43] estimated the reliability of the SISE to be .75.

Statistical analysis

Statistical analyses were performed using "Statistical Package for the Social Sciences" [44]. In order to avoid overoptimistic estimates of the efficacy of the training [45], an intention-to-treat analysis using the Last-Observation-Carried-Forward method was used [46]. Descriptive statistics were used to report means, standard deviations and frequencies. *t* tests and χ^2 were calculated to assess differences between groups, in age,

relationship duration (in months), sex, socioeconomic level, belief and symptoms measures: OBQ-20, OCI-r, PROCSI-Si, ROCI, DASS, and SISE. A series of repeated measures ANOVA with Bonferroni adjustments were calculated in order to evaluate pre-post scores in both study groups. The "Effect Size Determination Program" [47] was used to calculate Cohen's *d*.

Results

A total of 97 participants met the inclusion criteria and participated in the study. Mean scores for outcome measures and characteristics of groups 1 and 2 did not differ significantly at baseline (See Table 1).

Table 1. Descriptive statistics and comparisons between iApp group and dApp group in socio-demographic variables and outcome measures at baseline.

		iApp ($n = 51$)	dApp ($n = 46$)				
		M(SD)	M (SD)	t/χ^2	df	P	Cohen's d
Age		22.88 (9.23)	20.09 (2.73)	1.97	95	.05	0.4
Gender							
	Men	25.5%	10.9%	3.42	1	.06	0.37
	Women	74.5%	89.1%				
Socio-economic status							
	Low	3.9%	2.2%	3.64	3	.30	0.15
	Medium-Low	31.4%	19.6%				
	Medium	52.9%	71.7%				
	Medium-high	11.8%	6.5%				
Duration relation. (months)		45.37 (86.96)	19.30 (14.78)	2.00	95	.05	0.4
OCI-R		1.79 (0.57)	1.78 (0.40)	0.09	95	.92	0.02
OBQ-20		3.24 (0.96)	3.08 (0.84)	0.84	95	.40	0.17
ROCI-S		1.76 (0.69)	1.73 (0.61)	0.24	95	.81	0.05
PROCSI-Si		1.66 (0.57)	1.62 (0.69)	0.29	95	.77	0.06
DASS-D		1.74 (0.67)	1.53 (0.49)	1.74	95	.08	0.35
SISE		3.12 (1.09)	3.37 (0.97)	-1.20	95	.23	0.24

iApp: immediate use App; dApp: delayed use App. OCI-R: Obsessive-Compulsive Inventory-Reduced; OBQ-20: Obsessive Beliefs Questionnaire-20; ROCI-S: Relationship Obsessive–Compulsive Inventory-Short version; PROCSI-Si: Partner-Related Obsessive–Compulsive Symptoms Inventory; DASS-D: Depression, Anxiety, Stress Scale-Depression; SISE: Single-Item Self-Esteem Scale

At 15 days (T2), 79 of 97 participants (81.4%) completed the study and 62 of 97 (65.1%) completed at the 15-days follow-up (T3). Participants who dropped out during the study period did not differ according to age (t_{95}=0.58, P=.56), gender (χ^2_1=3.36, P=.79), relationship duration (t_{95}=0.04, P=.97), or socio economic status (χ^2_3=3.36, P=.34) compared to participants who did not drop out (for flow diagram see Figure 3).

Figure 3. CONSORT flow diagram of participants through the trial.
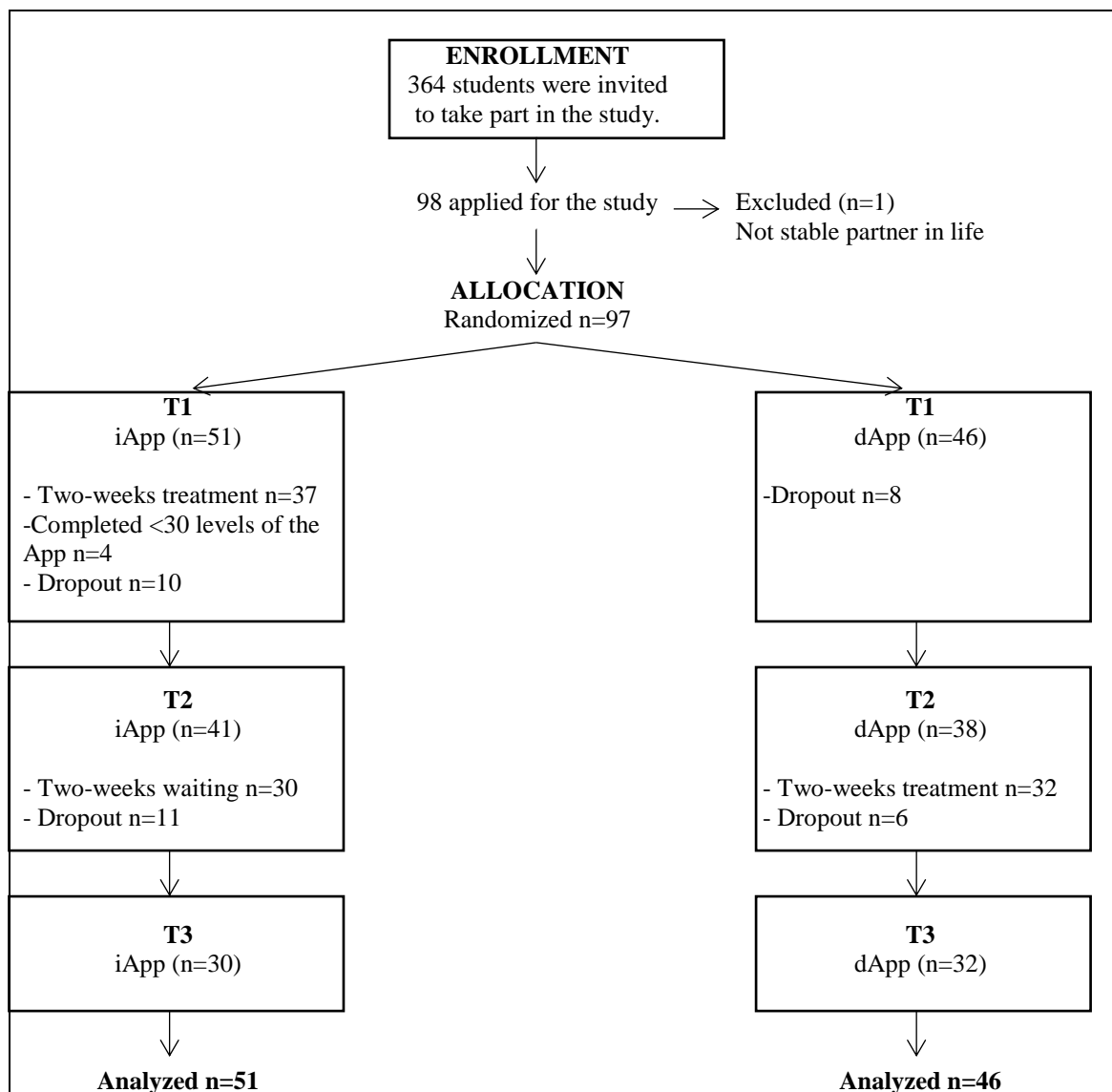
Tables 2 and 3 depicts the means and standard deviations for App intervention first (iApp) and waiting list control (dApp) participants, respectively, on all measures and testing occasions. All the participants used the app for a mean 14.07 (SD=1.41) days with a mean of 2.94 (SD=0.37) levels per day. Additionally, the highest level completed by participants was mean 40.93 (SD=10.20) of the 45 levels. There were no significant differences between the two groups with regard to days used, mean of levels per day and highest level achieved. *Between-Group Differences (iApp group Versus dApp group)*

Analyses of the first two assessment occasions (T1 and T2) revealed significant Treatment × Repeated Measures interactions on OBQ, $F(1,95)$=17.06, P<.001, d=0.84, PROCSI-Si, $F(1,95)$=4.28, P=.04, d=0.42, and SISE, $F(1,95)$=4.36, P=.04, d=0.42. These results indicated that students in the iApp (App first) exhibited lower OCD-related beliefs, partner-focused ROCD symptoms, and increase self- esteem than their waiting list counterparts on the second assessment occasion (See Figure 4).

Figure 4. Graphics of the measures across T1, T2 and T3 for iApp group and dApp group.
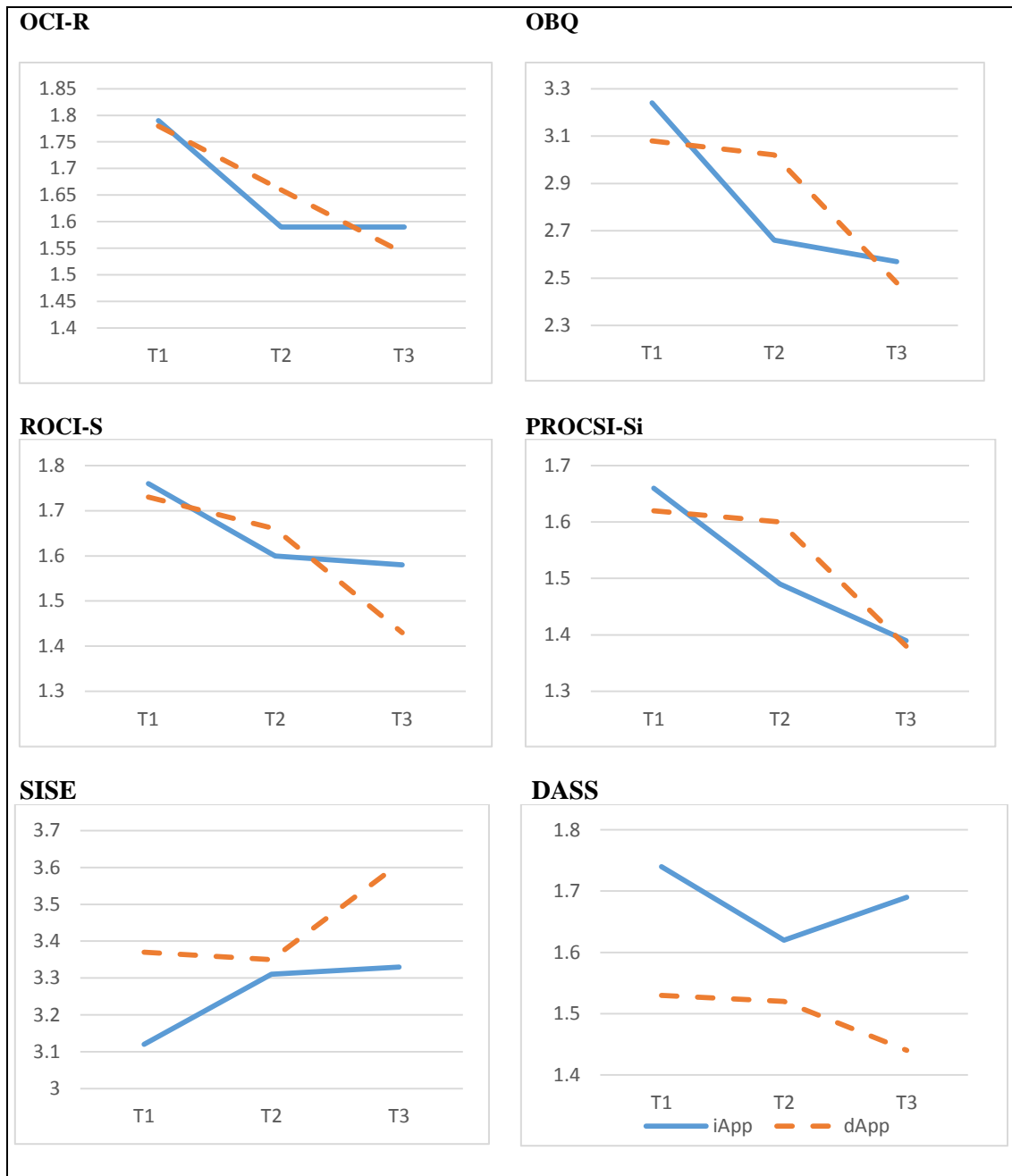
iApp group Within-Group Effects and 15 days Follow-Up Effects

In iApp group (App first), we expected pre-post reduction in OCD related beliefs and symptoms, as well as retention of these effects in the follow-up period. Thus, pre-to-final changes were specifically examined via ANOVA repeated measures between T1-

T3 and between T2-T3. A significant decline between pre-to-final changes was found on the OBQ, the OCI-R, the PROCSI-Si, the ROCI-S, and the SISE. Further, the differences found between T1 and T2 were maintained in T3. Moreover, the only statistically significant difference found was on PROCSI-Si scores that indicated an additional significant improvement between T2 and T3 (see Table 2).

Table 2. Descriptive statistics and comparisons among times for iApp group.

	T1	T2	T3	T1 vs T3			T2 vs T3		
				$F_{(1,50)}$	P	d	$F_{(1,50)}$	P	d
OCI-R	1.79 (0.57)	1.59 (0.50)	1.59 (0.49)	10.87	.002	0.65	0.00	.99	0
OBQ-20	3.24 (0.96)	2.66 (1.10)	2.57 (1.18)	51.39	<.001	1.42	1.20	.28	0.21
ROCI-S	1.76 (0.69)	1.60 (0.62)	1.58 (0.63)	5.65	.02	.47	0.07	.79	0.05
PROCSI-Si	1.66 (0.57)	1.49 (0.55)	1.39 (0.48)	30.00	<.001	1.109	5.98	.02	0.48
DASS-D	1.74 (0.67)	1.62 (0.64)	1.69 (0.69)	0.53	.47	0.14	3.84	.06	0.39
SISE	3.12 (1.09)	3.31 (1.14)	3.33 (1.21)	7.13	.01	.53	0.11	.74	0.06

OCI-R: Obsessive-Compulsive Inventory; OBQ-20: short form of the Obsessive Beliefs Questionnaire; ROCI-S: Relationship Obsessive–Compulsive Inventory-Short version; PROCSI-Si: Partner-Related Obsessive–Compulsive Symptoms Inventory-Six item version; DASS-D: Depression, Anxiety, Stress Scale-Depression subscale.

dApp group Within-Group Effects

In dApp group (waiting list), we expected that cross-over (i.e., beginning to use the app) would be associated with a significant decrease on OCD beliefs and symptom measures. Indeed, within-group differences between T2 and T3 following the cross over, indicated significant reduction on the OBQ, PROCSI-Si, ROCI-S, and SISE scores. No differences were found on the DASS.

Unexpectedly, participants showed a significant decrease on OCD symptoms (OCI-R) between T1 and T2. Nevertheless, additional significant reduction on OCI-R scores was found between T2 and T3 on the OCI-R (see Table 3).

Table 3. Descriptive statistics and comparisons among times for dApp group.

	T1	T2	T3	T1 vs T2			T2 vs T3		
				$F_{(1,45)}$	P	d	$F_{(1,45)}$	P	D
OCI-R	1.78 (0.40)	1.66 (0.36)	1.54 (0.32)	7.28	.01	0.56	9.09	.004	0.61
OBQ-20	3.08 (0.84)	3.02 (1.03)	2.48 (1.04)	.41	.53	0.13	27.52	.001	1.07
ROCI-S	1.73 (0.61)	1.66 (0.62)	1.43 (0.38)	1.70	.20	0.27	12.52	.001	0.72
PROCSI-Si	1.62 (0.69)	1.60 (0.72)	1.38 (0.50)	.10	.75	0.06	9.41	.004	0.62
DASS-D	1.53 (0.49)	1.52 (0.50)	1.44 (0.37)	.00	.96	0	2.35	.13	0.32
SISE	3.37 (0.97)	3.35 (1.01)	3.61 (0.91)	.07	.78	0.05	6.75	.01	0.53

OCI-R: Obsessive-Compulsive Inventory; OBQ-20: short form of the Obsessive Beliefs Questionnaire; ROCI-Short version: Relationship Obsessive–Compulsive Inventory; PROCSI-Si: Partner-Related Obsessive–Compulsive Symptoms Inventory-Six item version; DASS-D: Depression, Anxiety, Stress Scale-Depression subscale.

Discussion

Mobile applications based on CBT principles have unique advantages including wide reach, continuous availability, appeal to young people, very low cost and progress monitoring. There is accumulating evidence that such applications can lead to significant reductions in psychopathological symptom and maladaptive behaviors [48–50]. The present randomized control study evaluated the efficacy of a mobile application platform named GGRO, which was designed to challenge OCD related maladaptive beliefs. Consistent with a previous exploratory investigation [24], our results indicated that 15 days of brief daily training using GGRO lead to significant reductions in OCD-related beliefs. Moreover, reductions in OCD related beliefs were

maintained for a follow up period of 2 weeks. These results provide support for the stepped-care approach for OCD [8], suggesting that OCD-related beliefs and symptoms can be reduced using low intensity, alternative modes of treatment delivery.

Relative to a waitlist control group in our study, individuals using GGRO for two weeks showed lower OCD-related beliefs, ROCD symptoms, and increased self-esteem. Moreover, the change produced after the training was maintained stable after 15 days follow-up. Once our waiting list group started using GGRO (after crossover), participants in this group showed a reduction in OCD-related beliefs, OCD and ROCD symptoms. Interestingly, an exception was partner-focused OC symptoms, which showed further improvements at follow-up, indicating a generalization of results and suggesting that the maladaptive beliefs targeted in GGRO may be particularly relevant to this ROCD presentation. Indeed, GGRO includes levels related to partner-value contingency of self (i.e., self-esteem that is overly dependent on the partner's perceived value [51]), which may be particularly pertinent to partner-focused ROCD symptoms [52]

Unexpectedly, OCD symptoms declined in both the iApp and dApp groups during the initial two weeks. Fluctuations in the intensity of student requirements/evaluations may have coincided with the time period of our study and attenuated participants' OCD symptoms in the waitlist group. Indeed, most of the student data were collected during mid-semester, a period when students see a decrease in their exams and other evaluations. Importantly, however, using GGRO was associated with a further reduction in OCD symptoms following cross-over, thus supporting the efficacy of GGRO in reducing OCD symptoms.

Consistent with a previous study [24], levels of depression did not show any statistically significant change. Indeed, GGRO was specifically designed to target OCD-

related beliefs and symptoms. GGRO was not designed to challenge depression related maladaptive beliefs per-se (e.g., hopelessness and helplessness) and therefore does not include content designed to challenge depression related beliefs. Considering participants' depression levels were relatively low, this may explain depression symptoms did not show significant reduction.

Our findings are consistent with previous research showing the efficacy of CBT based applications in cognitive and behavioral change [53,54]. According to these models, commonly occurring intrusive experiences escalate into obsessions due to their catastrophic misinterpretations [12]. Strongly held, maladaptive beliefs such as perfectionism, exaggerated importance attributed to the content of thoughts or their occurrence and low tolerability for uncertainty increase the likelihood of such catastrophic interpretations.

The app evaluated in this study, was designed to challenge maladaptive beliefs associated with OCD. By introducing to users interpretations that are inconsistent with their OCD related beliefs, adherence to such beliefs was expected to weaken. This, in turn, was expected to reduce catastrophic interpretations of intrusions and decrease OCD symptoms. Indeed, previous findings showed that change in OCD-beliefs levels in users of GGRO were associated with reduction in OCD symptoms over and above OCD symptom levels before using GGRO [24]. Consistent with this, the results of our study suggest that daily training involving users' actively responding to catastrophic interpretations of intrusions and their alternatives was shown to lead to significant reduction in maladaptive beliefs and associated symptoms.

Although the findings of our study are consistent with expectations, our study has some important limitations. The sample used in our study comprised of mainly female students from the general population. Indeed, the prevalence of OCD has been

observed to be equal between men and women. Recent reviews support the utility of nonclinical participants in OCD related research [32]. Moreover, initial evidence suggests using the GG platform with individuals presenting with OCD [55] may reduce OCD-related beliefs and symptoms. Nevertheless, clinical populations may be distinguished from non-clinical participants in symptom-related impairment. The lack of such symptom related impairment in non-clinical participants may facilitate reduction in OCD-related beliefs and symptoms compared to a clinical population. In addition, the absence of mental disorders was not confirmed by clinical interviews. Future studies may benefit from evaluating the usefulness of GGRO in individuals with OCD.

Previous research using similar methodologies showed comparable dropout rates [56,57]. We also performed intention-to-treat analysis with the Last-Observation-Carried-Forward method [46] to prevent overestimation of treatment effects. Nevertheless, care should be taken in the interpretation of our results and future studies may benefit from the use of additional dropout reduction strategies (e.g., monitory or course credit compensation).

The great majority of mobile applications designed for OCD are oriented to be a self-applied therapy, and some to track and/or guide exposure with response prevention [58,59]. However, their efficacy has not been empirically demonstrated with controlled studies [23,60]. In this regard, this randomized control study further our knowledge about the efficacy of alternative CBT delivery systems for OCD.

GGRO was designed as a brief and easy training platform to challenge maladaptive beliefs and associated interpretations of thoughts and events. As such, this platform could complement traditional CBT interventions as inter-sessions work and/or relapse prevention tool, thus, being an instrument at the service of the therapist, not as a way to replace it. Moreover, this cost effective and accessible mobile platform could

also be used in at risk populations of OCD and related disorders to reduce levels of maladaptive beliefs. Future studies may assess the usefulness of similar applications to other symptoms such as body image distress and depression. Indeed, reducing levels of maladaptive beliefs in at risk populations using cost effective, accessible mobile platforms such as used in this study, may increase resiliency to a wide variety of psychological disorders. Moreover, such a platform may be useful for relapse prevention following treatment.

Conflict of interests

One of the authors (GD) is a co-developer of GGRO. GD is also a co-founder of GGapps.net. GGRO is the subject of this evaluation and therefore has financial interest to GGapps.net.

Abreviations

CBT: cognitive-behavioral therapy
dApp: delayed use group
DASS: short version of the Depression, Anxiety, Stress Scale
iApp: immediate use group
OCI-R: Obsessive-Compulsive Inventory
OBQ-20: short form of the Obsessive Beliefs Questionnaire
OCD: Obsessive compulsive disorder
PROCSI-Si: Partner-Related Obsessive–Compulsive Symptoms Inventory – Six-item version
ROCI-S: The Relationship Obsessive–Compulsive Inventory – short version
SISE: The Single-Item Self-Esteem Scale

Multimedia Appendix 1
CONSORT-EHEALTH V1.6.

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