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Leveraging Digital Technology to Intervene on Personality Processes to Promote Healthy Aging

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Abstract

The scientific evidence is clear that personality processes (particularly conscientiousness and neuroticism) play an important role in healthy aging. Assuming it would be desirable to assist individuals to change their personality in directions that would promote healthy aging, the next step is designing interventions for the task. During the past decade, technological advances have made it possible to develop and evaluate interventions delivered via web- and mobile- digital technologies. The purpose of this paper is to discuss the possibilities for leveraging technology to intervene on personality processes to promote healthy aging, with a specific emphasis on applications for older adults. We begin by reviewing interventions that target personality change to treat mental health problems and physical health, followed by the scant research leveraging digital technologies in targeting personality processes. We present a rationale for adopting a “transdiagnostic model” to guide intervention development and review the brief literature supporting transdiagnostic interventions when adapted for digital delivery (Transdiagnostic Internet-Based Cognitive-Behavioral Therapy, ICBT). We then summarize the literature on designing technology interventions to meet the specific needs of older adults, and some of the impressive results from digital technology (ICBT) intervention studies. We conclude with suggestions for addressing gaps in this important but understudied area of research, with a focus on research targeted to older adults.

Keywords

digital technology; mobile health; healthy aging; personality; personality change

Introduction

The purpose of this paper is to review and critically assess the potential for using digital technology (e.g., web, mobile technology) to impact personality to promote healthy aging. Digital technology has become widely accessible in virtually all populations worldwide

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Disclosure:

One of the investigators, Dr. Marsch, is affiliated with several businesses that develop and deploy mobile behavior change interventions (including Square2 Systems, Inc; HealthSim, LLC, and Pear Therapeutics). These relationships are extensively managed by Dr. Marsch and her academic institution.

(e.g., The White House, 2015; WorldBank, 2016) and may provide widespread access to therapeutic tools to promote healthy aging. In this paper, we review “face-to-face”, behavioral intervention studies, as well as the limited literature on digital technology interventions to promote healthy aging, in both the areas of mental health and physical health. We discuss some important considerations for designing web/mobile programs for the older adult user and the type of technologies currently being developed for older adults. We present a rationale for adopting a “transdiagnostic model” for cognitive behavioral intervention design, followed by reviewing the extant transdiagnostic internet-based cognitive-behavioral therapy (ICBT) research, and ICBT research for older adults. Finally, we review lessons learned from technology-based interventions for personality modification related to mental health among older adults (which is among the most well-studied areas in the field) to provide additional insights into the development of technology-based interventions targeting personality to promote healthy aging.

Personality and Healthy Aging

The Big Five personality traits are five broad domains comprising the Five Factor Model (FFM) that describes human personality (Costa & McCrae, 1992). The five factors are openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. These five personality styles have been identified across a wide range of cultures and ages, beginning with temperaments in childhood, and developing from adolescence and young adulthood through old age. Although as traits they tend to be highly stable over time, they have also been found to naturally change to some extent over time in individuals and across age group cohorts (B. W. Roberts, Walton, & Viechtbauer, 2006).

The Big Five Factors have been shown to predict all-cause mortality at a level comparable to factors such as cognitive ability and socioeconomic status (B.W. Roberts, Kuncel, Shiner, Caspi, & Goldberg, 2007). Conscientiousness (C) and neuroticism (N), in particular, appear to be associated with healthy, and unhealthy aging, respectively. For example, C has been associated with a reduced risk for many illnesses, such as depression, diabetes, hypertension, and stroke (Goodwin & Friedman, 2006), reduced functional limitations (Goodwin & Friedman, 2006; Krueger, Wilson, Shah, Tang, & Bennett, 2006), better quality of life (Chapman, Duberstein, Sorensen, & Lyness, 2006), greater productivity (Friedman, Kern, & Reynolds, 2010), and protection from Alzheimer’s Disease (AD), even in the presence of common AD-related neuropathologic changes (Wilson, Schneider, Arnold, Bienias, & Bennett, 2007). In contrast, N is frequently shown to be related to mortality (Wilson et al., 2005), increased risk of illnesses, such as depression, back pain, and asthma (Goodwin & Friedman, 2006), increased functional limitations (Goodwin & Friedman, 2006), worse physical health and well-being in old age (Friedman et al., 2010; Suls & Bunde, 2005), poor recovery from depression (Steunenberg, Beekman, Deeg, Bremmer, & Kerkhof, 2007), and suicide attempts (Wiktorsson et al., 2013). Indeed, the evidence supporting the link between these personality traits and health is so compelling that some have argued for routine screening for personality style in the primary care setting as a way to “personalize” health care (Israel & Moffitt, 2014).

In spite of the wealth of evidence linking personality traits to health outcomes, the mechanisms underlying these relationships are not yet clear, although they likely include a number of moderating and mediating factors, such as health-related behaviors, environmental circumstances, stressors, and socioeconomic status, which may vary across the life span (Shanahan, Hill, Roberts, Eccles, & Friedman, 2014). For example, high C has been shown to be associated with adherence to medical visits in both older and younger adults, and to be related to better medication adherence in older adults (Hill & Roberts, 2011). Furthermore, despite the wealth of evidence showing the predictive value of C and N on health, little work has been done to develop and evaluate interventions designed to alter these traits to promote health.

Interventions Targeting Personality to Improve Mental Health

The “modern era” of psychotherapy and psychiatric research may be said to have begun during the 1980s. The time-honored tradition of case series reports was replaced with the scientific methods employed by medical research; namely, randomized controlled study designs, a great methodological advance for the field. These changes also coincided with changes to the Diagnostic and Statistical Manual of Mental Disorders (DSM), which delineated symptom-based Axis I disorders, thus moving away from personality construct formulations of mental disorders. As a result, personality dimensions (such as the Big Five) have not typically been targeted for intervention nor measured in modern era psychiatry and psychology clinical trials, and certainly not as the primary outcomes of interest. Hence, there is little direct evidence from methodologically-rigorous clinical trials pertaining to change in personality traits.

Although there is scant intervention literature targeting personality modification, there is a wealth of research from the field of clinical psychology evaluating psychological therapies for the treatment of psychopathology which has direct implications for personality trait modification. A recent meta-analysis by Roberts and colleagues (B. W. Roberts et al., 2017) examined the question of whether personality traits changed as a result of treatment for common mental disorders, such as anxiety disorders and depression. Impressively, through their analysis, they sought to tease out the complicated question of whether measured changes in personality traits (most specifically N and extraversion; associated with poor and good mental health, respectively), if they do occur, could reasonably be attributed to true changes in the trait.

The investigators sought to answer the following questions: 1) do personality traits change in the context of therapeutic intervention?; 2) do traits change more in intervention conditions than in wait list control conditions?; 3) do traits change even with non-clinical intervention studies?; and 4) how long do the changes last? Their meta-analysis included 207 studies comprised of controlled experimental studies and uncontrolled “pre-post assessment” intervention studies with clinical populations (primarily depression, anxiety disorders and eating disorders), and intervention studies with non-clinical populations. They found that personality traits do change with intervention ($d=.37$; moderate effect size), and quickly. Effects reached asymptote by 8 weeks with longer treatments adding no further benefit. In controlled studies the intervention groups changed on average .43 standard deviations more

than control groups, which was consistent between clinical and non-clinical samples. This change is nearly one half the magnitude of change seen naturalistically from young adulthood through middle age. They also did not find a diminishment of the changes with passage of time following treatment; the average effect holding up at $d=.34$ immediately after treatment, $d=.48$ up to six months following treatment, and $d=.46$ up to one year following the end of treatment. In line with expectations, the largest effects were found for N, followed by extraversion, with little or no change found for other personality traits (e.g., C, agreeableness, and openness to experience). The authors interpret this finding as a “good sign,” stating that this specificity effects argues against simply a self-presentation of being “better.” For N in particular, cognitive-behavioral therapy was associated with the largest changes compared to other therapeutic modalities (e.g., supportive, psychodynamic). Relevant to the present paper, age was not a predictor of personality change; i.e., older adults showed similar positive changes as younger and middle aged adults. In sum, this work concluded that personality traits (particularly N and extraversion) do appear to change with therapy.

Several additional studies have shown a similar pattern. DeFruyt et al. (2006) assessed change in the Big Five personality traits over a 6 month period in a large sample of adults ($N=821$) diagnosed with major depression randomized to two different antidepressant medications and receiving (in a non-randomized fashion) one of three types of psychotherapy (supportive, cognitive-behavioral and psychodynamic) based on provider preferences. There were no differences in depressive outcomes across the treatment conditions, and all conditions resulted in substantial improvements. The covariance structure for personality traits also did not differentially change by condition over time, indicating substantial structural personality stability. Although all traits changed “slightly” in desired directions, the most substantial changes were found for emotional stability (i.e., reduced N). These changes occurred independently of improvements in depression, suggesting that the improvements in depression did not drive the measured changes in personality (i.e., absence of a “state effect”). Nonetheless, in the absence of a true control condition in which active therapeutic ingredients are not present, we cannot know from this study whether the changes in depression or personality were due to the treatments provided or other factors, such as spontaneous change, regression to the mean, or other unmeasured variables.

Tang et al. (2009) conducted a randomized controlled trial of antidepressant therapy (paroxetine; SSRI) and cognitive therapy (CT) compared to pill placebo while also measuring personality (N and extroversion) during treatment. A continuation phase (through 12 months), included a crossover condition in which SSRI responders were re-randomized to receive SSRI or placebo, placebo patients could choose to receive SSRI, while CT responders continued with CT booster sessions. The main effects showed that SSRI and CT produced equivalent outcomes on changes in depression, N and extroversion, and both were superior to placebo. Placebo patients also improved substantially on depression but not on N or extroversion, again not supporting a “state effect” hypothesis. However, when placebo patients were switched to SSRI, no further improvements were seen for depression, whereas N and extroversion improved significantly. For the CT patients, once depression improvement was accounted for in the analyses, improvements in N compared to placebo were no longer evident. On the other hand, after accounting for depression improvement in

SSRI patients, the improvements for N were still evident compared to placebo. Moreover, after accounting for personality improvement, the difference between SSRI and placebo for depression were no longer significant. Finally, reductions in N for SSRI predicted resistance to relapse (perhaps a “reverse” state effect), but this same effect was not found for CT despite CT being more efficacious in preventing depression relapse than the SSRI (Hollon et al., 2005).

Tang et al.’s findings suggest some interesting conclusions. First, they support the De Fruyt study findings indicating that the “state effect” of depression improvement does not appear to be responsible for changes in personality, at least for pharmacological treatment with an SSRI. Second, the SSRI appeared to have effects on personality that were independent of its effects on depression (i.e., pharmacological specificity for personality modification). Third, and perhaps most surprising, cognitive therapy appeared to exert its effects on depression independently of modifying personality. Personality improvement was no longer evident after accounting for depression improvement, and improvements in N did not reduce vulnerability to depression relapse. In summary, and somewhat counterintuitively, SSRI medications may have their effects on depression indirectly via biochemical manipulation of personality, and CT may exert its effects on depression directly, with personality changes although substantial and meaningful, representing epiphenomena.

Although the literature on digital therapeutic interventions for mental health is large (e.g., Naslund et al., 2017; Saddichha, Al-Desouki, Lamia, Linden, & Krausz, 2014), we found only one example of a digital technology intervention study focused on developing desirable personality traits to promote mental health. Sergeant and Mongrain (2014) examined a positive psychology online intervention to improve trait “optimism” in “pessimistic” individuals. Optimism (a positive outlook on life during good as well as difficult times) has been shown to be associated with positive affect, increased motivation, and goal engagement (Segerstrom, 2006). Furthermore, cultivating an “action-oriented” behavioral approach to life is thought to be as essential as the cognitive aspects of optimism (i.e., positive beliefs about oneself and one’s ability to succeed). Interventions to promote action and positive beliefs are arguably most effective when “matched” to individuals demonstrating deficits in the area being promoted. Thus, optimism interventions may be most effective for persons with a pessimistic outlook and demonstrating behavioral inhibition.

The internet-guided intervention led users through a process of listing things that make life enjoyable and worthwhile, followed by a goal setting process to identify how they would immediately act on these things. The control condition wrote about daily activities over the same intervention time period. The optimism intervention led to greater pursuit of engagement-related happiness and reduced dysfunctional attitudes. Moreover, these effects were most pronounced among participants who reported the highest pessimism levels at baseline and who showed greater reductions in depressed mood. However, these effects were only present during the active intervention period, suggesting that trait pessimism was not modified in an enduring sense.

Summary

Although traditional clinical trials for mental health disorders typically do not include measures of changes in personality traits, there is a wealth of *indirect* evidence supporting such changes, and these changes appear to reflect “real” changes to the trait rather than apparent changes owing to “state” change effects. The effect sizes are at least moderate, and change appears to happen quickly and sustain over time for up to one year. Cognitive behavioral interventions appear to be most effective in producing change in personality makeup and these changes occur across the age span, with older adults as likely to show these changes as younger persons. The benefits appear to be strongest for persons showing deficits in the area being targeted, suggesting that interventions “targeted” to personality deficits may perhaps show the greatest promise.

Interventions Targeting Personality to Promote Physical Health

As already noted, there is a wealth of evidence linking personality to physical health, longevity and mortality risk. However, interventions to modify personality as a means of improving physical health have been almost completely ignored in preventive medicine research and clinical practice (Israel et al., 2014). There are multiple likely reasons for this. Biomedical researchers are not likely to be familiar with the concepts of personality traits or the literature linking personality to physical health outcomes. Also, although proven to be largely untrue (See Roberts et al., 2006), personality traits are commonly still thought to be immutable, and therefore not a viable target for intervention. And finally, even if perceived as a viable target for change, assessing personality takes time, and there is little available time to be had in modern era primary health care settings.

We identified only three studies (two randomized controlled trials [RCTs], and one pre-post assessment study) of a psychosocial intervention *specifically targeting personality* to target health risk reduction; i.e., preventing substance abuse. Interestingly, these studies all evaluated the same intervention for preventing alcohol misuse in “high risk” school aged children, conducted in different countries. Conrod et al. (2013) randomly assigned 21 secondary schools in the UK to receive either a teacher-delivered personality-targeted intervention (Preventure), based on cognitive-behavioral and motivational enhancement principles, or a control condition consisting of standard drug education to students at “high risk” for future problematic alcohol use. This personality-targeted approach provided personality-“specific” coping skills to the high risk youth *before* the natural onset of drinking behavior. Notably, the intervention is designed to improve the management of the personality vulnerability per se, *not* alcohol use, as these youths were generally not yet consuming alcohol. Preventure is based on a cognitive-behavioral therapy model (Waldron & Turner, 2008) and incorporates motivational enhancement principles (Jensen et al., 2011). The cognitive-behavioral approach teaches targeted coping strategies to help mitigate the likelihood of “high risk” students going on to misuse substances. The motivational enhancement component is especially useful in targeting problematic behaviors where individuals experience significant ambivalence toward change; such as substance use. This component seeks to promote “prosocial behaviors” which may counteract the “high risk” personality profile (not specifically alcohol related, but traits which put the youth at risk for

alcohol misuse) by focusing on the students' personal motives for change guided by their valued life goals.

All participants were in the 9th year of schooling with a mean age of 13.7 (SD=.33) years. High risk students were identified using the Substance Use Risk Profile Scale (SURPS) (Woicik, Stewart, Pihl, & Conrod, 2009), a 23-item questionnaire which assesses personality along four dimensions known to be associated with addiction: sensation seeking, impulsivity, anxiety sensitivity, and hopelessness. Those students scoring at least 1 SD above the school mean on at least one of the dimensions were assigned to receive the Preventure intervention in the intervention schools. Follow up assessments were conducted at 6, 12, 18 and 24 months after the intervention. This extended period (up to two years following intervention) is a time period in which high risk youth typically begin problematic drinking. Using latent growth models for analysis, primary outcomes were change over time for drinking frequency, binge drinking, and drinking-related problems. Results showed that the high-risk students receiving the Preventure intervention had lower drinking rates (29% reduced odds; $p=.03$), lower binge drinking rates (43% reduced odds; $p=.03$) and lower problem drinking rates (29% reduced odds; $p=.02$) than the students in the standard education control condition over the 24 month follow up period. Change in personality was not measured, although the authors, citing their previous research showing that the high-risk personality traits do not change, suggested that the intervention modifies the way in which the students "manage" their at-risk personality style.

Newton et al. (2016) evaluated Preventure with school-aged children in Australia. They conducted a four-arm clustered RCT of the Preventure program compared to a "health education as usual" control condition, with a three year follow up period; notably the longest follow up period to date. Based on the SURPs (Woicik et al., 2009), the intervention again targeted "high risk" students demonstrating elevated scores (1 standard deviation or greater above the school mean) on at least one of the four personality traits associated with alcohol misuse. Fourteen schools and 438 students total were enrolled in the study. Participants were enrolled in their 8th year of schooling, and the mean age of students was 13.4 years (SD=0.47). The primary analyses assessed the impact of the intervention on rate of change over time on frequency of drinking and binge drinking, and alcohol-related "harms."

The Preventure program was comprised of two 90-minute group sessions delivered one week apart by qualified facilitators (clinical psychologists trained in the Preventure program) which focused on psychoeducation about the high risk target personality styles and a cognitive-behavioral model for understanding their coping behaviors, personalized by applying the concepts to their own personal experiences. Results from the study were impressive. Also applying the latent growth modeling procedure, and analyzing for the rate of change over three years in the three primary outcome measures, the main findings showed that Preventure students were less likely to consume alcohol ($b = .455$, $SE=.101$, $p<.001$), less likely to binge drink ($b = .652$, $SE=.209$, $p<.001$), and less likely to report alcohol-related harms over time ($b = -.255$, $SE=.096$, $p<.008$). These findings, once again, demonstrated that by teaching personality relevant coping strategies to address high risk personality traits, the cognitive-behavioral Preventure program reduced the likelihood of subsequent misuse for as long as three years following the program. As the authors note:

“Given that for every 1 year we can delay initiation to drinking, we can reduce the odds of developing an alcohol use disorder by almost 10% (Grant, Stinson, & Harford, 2001), delivering effective prevention is essential.”

A third RCT is currently underway in Canada, evaluating the Preventure program with a similarly high risk student sample (age 12–13) enrolled in grade 7, and followed for 12 months. Using the SURPS (Woicik et al., 2009), high risk students were identified in the manner described by Newton and colleagues (Newton et al., 2016) and were randomly allocated to the Preventure program or a usual health education control condition. While the trial is still underway, some interesting findings regarding intervention “process” variables have been reported for a sub-sample of 156 participants receiving the Preventure program that had reached the 12 month assessment point. Linear regression analyses, reporting R^2 for variance accounted for, showed that changes in self-esteem, coping, and cognitive distortions accounted for 25% of the variance in changes in alcohol use and 12% of the variance of changes in mental health symptoms. Most notably, skill development targeting personality deficits, such as cognitive restructuring and goal-setting, as reported by students via standardized interviews, were the most powerful. Students responding best to these approaches reported decreases or no change in alcohol use, and decreases in mental health symptoms over 12 months, whereas students not reporting these responses also reported increases in alcohol consumption over time. These findings suggest that teaching specific skills, which target the “management” of personality risk factors, may account for much of the success of health risk reduction interventions.

Summary

Very little work has been done to evaluate the effects of personality modification interventions on physical health or related health behaviors. One notable series of studies, which provided “personality-specific” intervention for students at high risk for developing alcohol misuse may offer a model for future intervention research. Such interventions could offer tools to manage personality “vulnerabilities” before a health risk behavior has the opportunity to express itself (e.g., drinking alcohol, using drugs, smoking cigarettes, engaging in risky sexual behavior), or at least early enough before the health risk behavior has the opportunity to instantiate itself.

Designing Technology Interventions for Older Adults

When considering the potential role for technology-based interventions to modify personality processes to promote healthy aging, it is important to consider important design features of technology interventions for older adults. Internet use among older adults (i.e., 65 years and older) has increased from 35% in 2008 to 60% in 2014, with two-thirds of internet users logging on daily (Smith, 2014). Also, as of 2014, 69% of older persons own a mobile phone, and 34% are linked to social media. Rates of technology use are increasing by as much as 5–10% each year across these technology mediums among older adults. The myth that older adults will not adopt new technology has been debunked, and as mid-lifers age, rates of technology use in the older population is expected to continue to skyrocket (Smith, 2014). Although promoting healthy aging through technology may be *convenient* for the

general population, for many older adults it is very possibly *essential*. The combination of physical health problems, functional disabilities, and financial and transportation limitations for this population make low cost, easily accessed, technological interventions of extremely high value.

Nevertheless, older adults using technologies do have special needs. For example, they have more technical challenges in using the technology, requiring more guidance and more specific instructions (Crabb et al., 2012). There are also age-related deficits, including impaired vision, problems with manual dexterity, and memory and cognitive challenges. Attitudinal barriers also play a role. For example, many older adults left the workforce before computer-assisted work functions became standard and therefore do not readily see the potential benefits of the technology and/or may fear technology or have low confidence in their ability to interact with the technology (Blaschke, Freddolino, & Mullen, 2009). Hence, older adults may require some initial, as well as ongoing, training and support.

Unfortunately, because the highest user groups of the Internet/mobile devices continue to be younger persons, limited attention has been paid to date on designing technologies with the older user in mind. However, perhaps because of the growing realization of the increasing utilization of technology among older adults, some recent efforts have focused on the needs, concerns, and preferences of the older technology user. Whether the intent is to promote personality change/development or to sell a product, the call has gone out for “user-centered” design (Nath & Sharp, 2015), “participatory” design (Grudin & Pruitt, 2002), “person-based” design (Yardley, Ainsworth, Arden-Close, & Muller, 2015) and the development of “personas” (Reeder, Zaslavsky, Wilamowska, Demiris, & Thompson, 2011) and other creative techniques (Blythe & Dearden, 2009) to facilitate building these technology systems with the end user in mind.

Participatory design actively engages the potential technology user both initially and over the long term in order to fully understand the needs and desires of the user (Grudin & Pruitt, 2002). This goes beyond the mere understanding of what the product is supposed to “do” (i.e., usability) Good participatory design includes a deeper understanding of the values, fears and aspirations of the user group, achieved through direct observation of the group (T. Brown, 2008). Participatory design also requires agile software development with rapid prototypes that are responsive to user feedback followed by rapid modification and retesting. These are user-centered approaches that should be employed with all user groups but which have seldom been applied with older users.

Another promising software development approach that is being recommended for guiding development with older adults, including the “oldest old” (e.g., 85 years and older), is the creation of “personas” (Grudin & Pruitt, 2002; Nath & Sharp, 2015; Reeder et al., 2011). Personas are fictional people or “archetypes” that have names, gender, educational achievement, and life stories based on observing and talking with the real people they are meant to emulate. Personas are constructed using interviews, focus groups, and analyses of existing data with real world applicability. Creation of such personas can be extremely effective in helping software and hardware developers target the characteristics of the end

user. Ultimately, they are meant to represent the real person that will interact with the technology system.

As an example, Reeder et al. describe the process of developing two persona, “Hazel” and “Rose,” who were meant to capture the differing abilities of the oldest old demographic group. A cluster analysis technique applied to survey data from the targeted population (85 years old) yielded two clusters; one associated with the idea of a younger persona with greater independence, and an older persona with diminished capabilities. From there, the researchers conducted focus groups, further developed the personas, and then subjected them to expert review to create a “true” story of the lives of Hazel and Rose. In the end, each persona had unique characteristics representative of their respective age cohort, related to age, education, medical conditions, computer experience, perceived health and functional status, cognitive status, and perceived social support.

Based on the processes leading to creation of the Hazel and Rose personas, the researchers offer eleven recommendations for conceptualizing and designing technologies for the oldest old: (1) consider the input device to be used: e.g., a one button mouse, or touch sensitive device (Note: Delello and McWhorter (2015) found that iPad devices have high acceptability by older adults, ostensibly because the graphical interface allows them to bypass all of the “small buttons (and) fiddly controls”); (2) maintain a consistent interface (e.g., do not vary instructions, shapes of buttons, formats or colors); (3) allow images and text to be resized (e.g., implement a “zoom” feature for all visual components); (4) provide clear instructions for how to control the interface (i.e., “hit Alt F10” may not mean anything to a novice older computer user); (5) clearly describe tasks to be completed; (6) clearly delineate tutorials for a task from the actual tasks to be completed; (7) ensure demonstration tasks match the difficulty of actual tasks to limit frustration and annoyance; (8) allow adequate time (which is typically longer for older than younger persons) between instructions and the start of tasks; (9) display progress through the task (e.g., “anchor” the person by displaying progress with a status bar); (10) allow tasks to be skipped to limit frustration and early discontinuation; and (11) clearly delineate when a task is complete.

Current Status of Technologies for Older Adults

Although the technology user needs of older persons have not figured prominently into software design to date, a number of health informatics technologies have nonetheless been developed to assist the older adult. Koch and Hagglund (2009) completed a literature review on this topic. They divided the report into 5 main clusters: information systems and decision support for care professionals, consumer health informatics (personal health records, self-assessment tools and web portals), emerging technologies, home telehealth (smart homes, ambient assisted living, telemonitoring), and informatics methods. Within and across these categories, the most commonly developed technologies for older adults are the “assistive technologies”, used to “increase, maintain or improve functional capabilities of individuals with cognitive, physical or communication disabilities” (Marshall, 1997). Such assistive technologies have largely targeted eight problem areas: dependent living, fall risk, chronic disease, dementia, social isolation, depression, poor wellbeing, and poor medication management.

Khosravi and Ghapanchi (2015) conducted a systematic literature review of these areas and the technologies employed to assist them. Based on their findings, they conclude that in all areas, with the exceptions of chronic illness and medication management, the technologies appeared to improve the outcome of interest. For example, sensor technologies are effective for assisting seniors with dementia who are at risk of falling out of bed by alerting caregivers. In addition, video games which engage seniors in various physical activities also reduce fall risk. Robotics which engage an individual with a robot on a regular basis, and regular use of general communication technologies such as email and social media are effective for reducing depression, ostensibly by reducing social isolation.

As reviewed above, these technologies are of great benefit to many, but to date, to the best of our knowledge, there have been no technologies developed specifically for personality change to promote healthy aging. However, some areas of research, although not targeting personality change per se, may lead to outcomes which do facilitate personality change. For example, Callan et al. (2015) evaluated the feasibility of a pocket-PC cognitive control training program in an uncontrolled study with dementia caregivers. This program provided directed training in cognitive functions such as working memory, attention, and problem solving. These cognitive functions are related to executive function as well as personality traits, particularly with respect to emotion regulation and impulse regulation. These functions of the executive control system play profound roles in inhibiting impulsivity and promoting adaptive planning and goal oriented behavior; essential components of C. Callan et al.'s intervention asked elderly caregivers to practice a paced visual serial addition task involving adding serially presented digits in working memory which employs prefrontal brain processes important for executive control. Results showed that performance on the task improved significantly, by nearly 50%. Without specific efforts to promote use, they found that 74% of participants spontaneously used the tool at least 18 times, suggesting that it holds intrinsic interest and engages the user. Whether the improvements generalize to other aspects of executive functioning, including increasing C, remains to be seen, but examining this effect would seem to hold promise.

Summary

Digital technology use among older adults is growing at an astonishing rate, and as the population ages it will grow exponentially. Providing technological solutions to improving access to treatment and prevention for older adults is essential given their age-related problems, such as functional disabilities, and challenges with finances and transportation. In addition, special needs unique to the older adult (e.g., low vision, fine motor coordination, lack of computer skills) must be considered in the design of the technology. Overall, the use of user-centered design strategies which directly respond to the unique characteristics of the user is perhaps one of the most important considerations when designing interventions for older user groups.

The Transdiagnostic Model

A growing body of evidence indicates that various psychological disorders (e.g., anxiety and mood disorders) perhaps share more in common with each other than they are different (i.e.,

a *negative affect syndrome*; Barlow, Allen, and Choate (2004), with N as a central unifying factor), and suggesting that an intervention sharing a common set of principles may be at least, or even more effective than treatments targeting specific disorders. These disorders frequently co-occur (Kessler, Chiu, Demler, Merikangas, & Walters, 2005), share similar genetic risk factors (Hettema et al., 2006), similar mechanisms such as rumination and avoidance (Aldao & Nolen-Hoeksema, 2010), and temperamental characteristics including negative affect or N (Griffith et al., 2010).

Norton and Paulus recently reviewed the theoretical and empirical evidence supporting the validity of adopting a transdiagnostic model for anxiety disorders (Norton & Paulus, 2017). Across the anxiety disorders and anxiety-related disorders (e.g., panic disorder, social phobia, obsessive-compulsive disorder), it has been observed that although differing in observable content (e.g., avoidance of public speaking in social phobia and avoidance of dirty door knobs in obsessive compulsive disorder), these disorders share specific ontological features. Specifically, each disorder has an environmental or internal eliciting threatening stimulus, a cognitive misinterpretation related to that stimulus (generating an anxious or fearful affective state), and an escape and/or avoidance action tendency when exposed to the stimulus; representing a “core cognitive-behavioral-affective” process.

Norton and Paulus (2017) examine the wealth of evidence arguing for a transdiagnostic model. The comorbidity between anxiety disorders is high at approximately 55% (and even higher with depressive disorders at 76%) (T. A. Brown, Campbell, Lehman, Grisham, & Mancill, 2001). This presents the possibility that these are actually not distinct disorders, but different morphologies of a common underlying substrate. These diagnoses are also notoriously unstable over time, shifting across diagnostic categories over as short a time period as just two years (Hovenkamp-Hermelink et al., 2016); further evidence for their commonality. Genetic and heritability studies (showing 30–40 percent heritability) (Hettema, 2008) suggest transmission of *any* anxiety or depressive disorder rather than a diagnosis-specific genetic influence, more closely related to N than a specific pathology (Hettema, 2008). Likewise, the neurobiological evidence shows amygdalo-cortical activity to be common across all disorders, *not* disorder-specific circuitry (Britton & Rauch, 2009). Finally, CBT intervention studies show equivalent treatment effects across diagnoses (Norton & Price, 2007), and transdiagnostic effects in which untreated co-occurring anxiety and depressive disorders improve substantially and remit, following treatment for the “primary” disorder (e.g., Allen et al, 2010). Also, Norton and Paulus (2017) make the interesting observation that dosage levels for commonly prescribed serotonergic medications are highly similar across anxiety diagnoses, and result in high remission rates for co-occurring depressive disorders as well. They conclude that there is more evidence to support a transdiagnostic model for anxiety disorders (and perhaps depressive disorders as well) than as discrete pathologies. And, common “trans-disease” processes are also evident in many other health behaviors, as reflected from the self-regulation literature as well as neuro-behavioral research reflecting commonalities in underlying brain circuitry and circuit dysfunction associated with an array of health disorders (Bickel, Quisenberry, Moody, & Wilson, 2015; Morgenstern, Naqvi, Debellis, & Breiter, 2013).

In light of this type of growing evidence, a movement is taking place to develop and evaluate transdiagnostic interventions that address these commonly existing features of both anxiety and depressive disorders as well as other areas of health behavior. In addition to the theoretical and empirical reasons delineated above, there is also great practical value in doing so. Rather than learning a separate treatment protocol for each disorder (and the attendant difficulties with disseminating all such interventions), clinicians could learn a common set of guiding concepts they can use to construct therapeutic interventions that they modify “as needed” based on the presentation context of the specific case.

In their seminal work “Toward a Unified Treatment for Emotional Disorders”, Barlow, Allen and Choate (2004) present the framework for such an approach. The “unified treatment” would include three fundamental therapeutic components: a) altering antecedent cognitive appraisals, b) preventing emotional avoidance, and c) facilitating action tendencies. Altering antecedent cognitive appraisals involves re-evaluating the rationality of negative/threat appraisals before they give rise to strong negative affective states. Specifically, these reappraisals should target “probability overestimation” of a negative event happening, and “catastrophizing” the consequences of that negative event if it were to happen. The intervention also targets the efforts, sometimes frantic, to “down-regulate” or avoid the experience of negative emotional states. They point to research showing how attempts to use “calming” techniques (e.g., relaxation) as a specific strategy to control unpleasant emotional states may in some cases lead to the opposite effect, an escalation of these feelings, whereas an “acceptance” approach leads to a reduction of the experience. The third component relates to preventing the escape and avoidance action tendencies and facilitation of different (approach) tendencies. Thus, the intervention protocol should provoke the negative affective state in some fashion while promoting adaptive cognitive re-appraisal and approach rather than avoidance behavior. Evidence suggests that face-to-face transdiagnostic interventions, based on the principles of such a Unified Protocol, for mixed anxiety and depressive disorders may be as effective as disorder-specific treatments (McEvoy, Nathan, & Norton, 2009).

Summary

If technology interventions are to have the greatest impact, they should optimally be designed in a manner that meets the needs of the greatest number of potential users. Fortunately, it now appears that common facets of N in particular are represented across mental disorders as a “core” “cognitive-behavioral-affective” process. These shared ontological features perhaps now make it possible to develop “transdiagnostic” interventions to address common shared deficits rather than to develop unique treatments to address each of the many emotional disorders. A “unified treatment” adapted for technology delivery would offer a level of scalability not previously imagined. Early studies of transdiagnostic approaches are showing impressive effects that are comparable to disorder-specific interventions, and with moderate to large effect sizes.

Transdiagnostic Internet-Based Cognitive Behavioral Therapy Research

Recently, transdiagnostic internet-based cognitive behavioral therapy (ICBT) programs have been developed and evaluated for anxiety and depression. Given that the transdiagnostic theoretical model assumes that neuroticism is an underlying and potentially modifiable construct of anxiety and depressive disorders, some of these studies have also specifically measured changes in neuroticism. Titov and colleagues (Titov et al., 2011) employed a transdiagnostic ICBT intervention (*Wellbeing Program*) with individuals with one of three anxiety disorders (panic disorder, generalized anxiety disorder, or social phobia) or major depressive disorder. The intervention was compared to a waitlist control condition. Seventy-five participants were randomized to the two conditions. Eighty-one percent of treatment group participants completed all 8 sessions over a 10 week period, with little attrition at follow-up. Significant between-group differences were found at follow-up for anxiety and depressive symptoms with moderate effect sizes (Cohen's $d=.52$ and $.58$, respectively). This study used the NEO-Five Factor Inventory-Neuroticism Subscale (NEO-FFI-N) to measure N (Costa & McRae, 1992). Results showed significantly lower post-treatment scores on the NEO-FFI-N for the treatment group versus the control group ($p<.007$). Pre- to post-treatment and Pre- to follow-up within group effect sizes for N were moderate to borderline large ($d=.69$ and $.67$, respectively), and the post-treatment between-group effect size was moderate ($d=.47$).

A more recent trial also investigated the effectiveness of a 6-session transdiagnostic ICBT program: *Worry and Sadness Program* (Newby et al., 2013). This program placed particular emphasis on dealing with maladaptive rumination and worry; aspects of N which are proposed to be key maintaining factors for depression and anxiety (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). Study 1 consisted of a randomized controlled trial of the program (with therapist assistance), while Study 2 consisted of deploying the program under naturalistic conditions in primary care (with primary care clinicians providing assistance). In Study 1, 93 participants with major depression, generalized anxiety disorder or co-occurring disorders were randomized to the program or to a wait-list control condition. Adherence to the program was high, with 89% of participants completing all six sessions. Significant between-group differences were found ($p<.001$) and large within (at post-treatment and 3 month follow-up for the treatment group) and between group effect sizes (at post-treatment) were observed for the primary outcome measures of anxiety and depression ($d's>0.8$). Large within and between group effect sizes were also seen at post-treatment for the NEO-FFI-N neuroticism measure ($d's>0.80$).

In study 2, in which the program was deployed under primary care standard treatment conditions (i.e., open label study design) under the direction of primary care clinicians ($N=136$), the results were more mixed. Only 41% of participants completed all six sessions, but within-group effect sizes remained large ($d>.80$). A number of potential predictors of dropout were examined but none were found to predict who would drop out of the program. The investigators identified that 30% of participants that dropped out had achieved a substantial improvement (>1 standard deviation improvement on a psychological distress scale) at the time they dropped out, suggesting that individuals stopped using the program when they experienced a benefit. Nevertheless, the high dropout rate under “real world”

circumstances without research level assistance supports the accumulating evidence that a relatively high degree of human assistance is necessary to keep individuals engaged with the ICBT programs. Study 2 did not include a measure of neuroticism.

ICBT with Older Adults

Few studies of ICBT have been conducted specifically with older adults, and older adults are generally underrepresented in randomized controlled studies of ICBT with mixed age samples. This is true even though technology-supported mental health interventions may serve a greater need in this age group, as only 30% of older adults with a mental health disorder seek treatment due to barriers including stigma, mobility limitations, costs, and low mental health literacy (Trollor, Anderson, Sachdev, Brodaty, & Andrews, 2007). Older adults (defined as 65 years) comprise only 3% of the study samples (Crabb et al., 2012), whereas they make up approximately 20% of the population in the countries where the studies were conducted (primarily in Europe, North America and Australia). Engagement of older adults with technology has been a source of concern for researchers and clinicians alike. In spite of these concerns, however, when older adults do get included in clinical trials, they are actually *less* likely than younger adults to drop out of treatment (Crabb et al., 2012).

A survey administered to older adults (ages 65–86+) receiving psychiatric care showed that 50% were interested in using computer-based CBT and were willing to learn the necessary computer skills (Elsegood & Powell, 2008). We identified only a handful of studies of ICBT with older adults for the treatment of depression or anxiety. Interestingly, only one of the reports of studies conducted with older adults indicated that they used software designed or modified with the older adult user in mind, and none included computer skills training. Each included participants 60 years of age or older, with all studies conducted in Australia, with the exception of one conducted in Canada. Dear et al. (2013) conducted a single-arm feasibility trial of ICBT for depression. Participants were selected based on a PHQ-9 score >9 (cutoff score for clinically significant depressive symptoms; (Kroenke, Spitzer, & Williams, 2001) and were provided access to five sessions using the *Managing Your Mood Program*. Like most ICBT interventions in the research literature, the participants were also supported by regular contact with a therapist (in this case by phone and email). Completion rates were high, with 80% of participants completing the five sessions, and participants improved significantly in their depressive symptoms, demonstrating large effect sizes. Interestingly, although not specifically targeted for intervention, participants also reported significant improvement in their cognitive performance (moderate effect size), suggesting that as depression improved, cognitive dysfunction was also affected positively.

Mewton et al. (2013) completed a naturalistic study of an ICBT intervention with patients referred by their primary care provider to use the program through the *This Way Up* clinic. Patients were diagnosed with major depression, generalized anxiety disorder, panic disorder or social phobia by their primary care provider. Participants were provided access to six fully automated, unassisted lessons including psycho-education, behavioral activation, cognitive restructuring, problem solving, graded exposure, and relapse prevention and assertiveness skills; all components specifically designed to address each of the four disorders. This very large sample (N=2413) was comprised of all ages, including 225 participants age 60 and

older. As was found in other research, older participants were actually *more* likely than all of the other age groups to complete all six sessions (70% completion rate). They also experienced significant improvements in general psychological distress and quality of life.

Titov et al. (2015) recently reported the results of a preliminary cost-effectiveness study of ICBT (*Managing Your Mood Course*) with older adults with depressed mood ($n=29$) compared to a wait list control condition ($n=25$). Eligibility was determined by a PHQ-9 score >9 , and the mean age in this trial was 65 years. Weekly contact with a psychologist was provided by phone or email for an average total of 45 minutes per participant over the course of the study. Once again, there was a high completion rate, with 70% completing all eight sessions over an eight-week period. At post-treatment, ICBT participants scored significantly lower on depressive symptoms than the control condition (Cohen's $d=2.08$; large effect), as well as on anxiety symptoms (Cohen's $d=1.22$; large effect), and these effects remained at 3- and 12-month follow-up. In addition, the ICBT group had slightly higher Quality-Adjusted Life-Years (QALY's) than the control group, and while being of higher cost to implement than the wait list condition, the ICBT intervention was judged to be cost-effective based on Australian estimates of "willingness-to-pay" thresholds.

A similar study investigating ICBT treatment effects for symptoms of anxiety in older adults has recently been reported (B. F. Dear et al., 2015). This study randomized older adults (mean age=65) to an ICBT intervention (*Managing Stress and Anxiety Course*) ($n=35$) and a waitlist control condition ($n=37$). In this program the investigators included "age appropriate case examples," which was their attempt to tailor the intervention for older adults and which is rarely seen for technological interventions for this population. Therapist guides were included in the intervention and were instructed to attempt to contact each participant weekly by phone or email (based on participant preference) for brief 5–10 minute support calls. Significant differences were found between the conditions at post-treatment, with large between group effect sizes for both anxiety and depressive symptom severity scores (Cohen's $d=1.43$ and 1.79 , respectively). Mean therapist time was 58 minutes per ICBT participant. Cost effectiveness modeling indicated at least a 95% probability of being cost-effective.

Most recently, Jones et al. (2016) conducted a randomized controlled trial of ICBT for generalized anxiety disorder in older adults ($n=24$) compared to a waiting list control group ($n=22$). The ICBT intervention consisted of seven weekly modules, as well as weekly contact from a therapist guide via email to provide support, guidance, advice, and encouragement. Additional contact with the therapist was also encouraged via weekly "check ins" through the program. A "partial replication" research design was used in which the waiting list group was offered ICBT following the completion of their participation in the randomized trial. The average age of participants was 65 years (Range=60–80 years). Participants were enrolled based on meeting diagnostic criteria for generalized anxiety disorder (GAD) and scoring in at least the moderate range on a GAD severity measure. To evaluate potential predictors of who would respond best to ICBT, each participant completed measures of treatment credibility (i.e., how believable, convincing, and logical the treatment is) and expectancy for improvement from ICBT.

Adherence to the ICBT intervention was strong, with participants averaging 43 logins to the website, completing 6.32 of the seven modules, and sending 8.77 messages to the therapist. Significant differences ($p=.011$) and large between group effect sizes were observed both on measures of anxiety and depressive symptom severity (Cohen's $d=.85$ and 1.17 , respectively). Improved anxiety symptoms were observed through a one month follow-up period, although this was not seen for depressive symptoms. An impressive 86% of ICBT participants met the study criteria for GAD remission at post-treatment, whereas only 42% of control participants met this criterion. Regarding the predictors of response to ICBT; participants who rated the credibility of the intervention higher at pre-treatment showed faster decreases in anxiety symptoms than those rating ICBT as less credible. No effects were found for the expectancy measure.

Summary

Collectively, these studies provide compelling evidence that ICBT interventions can be effective for treating anxiety and depression in older adults, and that despite initial pessimism on the part of mental health experts, this population engages well with the technology (perhaps even better than younger populations). However, many additional questions, challenges and areas for future research remain. First, although these studies improve upon the very low representation of older adults in mixed age trials, the average age is still only 65 years. Hence, they offer little information on the effectiveness of ICBT for engaging and treating anxiety and depression in the ever-growing numbers of the very oldest persons in our society. Second, to date, little attention has been paid to designing technology with the special needs of the older adult user in mind (e.g., method of presenting the material, response requirements, and attitudes that could present barriers to their use) and methods of participatory design have not been employed. This may be particularly important for the very old population. Third, when education data are presented for research samples, participants almost always are around 50% college educated. Hence, they offer little generalizability to lower educated populations. Fourth, the randomized trials were conducted with a rather small number of participants (typically only 20–30 per condition), and in future research larger samples are indicated to identify subgroups that are more (or less) likely to benefit and to suggest relevant modifications to the interventions. Fifth, aside from therapist support and treatment credibility, we have little information regarding the mechanisms of treatment effects. Although the therapeutic relationship established with ICBT appears to be comparable to that developed in face-to-face therapy (Sucala et al., 2012), it is still unclear whether the quality of the relationship is associated with treatment outcomes (Knaevelsrud & Maercker, 2006; Sucala et al., 2012). Finally, for older adults, all studies have been either single arm open trials or have employed waiting list or no treatment control conditions. To our knowledge, there are no studies employing credible comparators (e.g., pill placebo, supportive therapy, relaxation training) controlling for the influence of the added attention received from study therapists and research staff on study outcomes.

Technologies for Personality Change: Future Research Directions

As reviewed above, to our knowledge, no technology application has been developed to date specifically targeting personality change for healthy aging. However, there are a number of

opportunities for new lines of research to build on the relevant literature to date to explore this important scientific question. Toward this end, based on the promising empirical literature to date, the transdiagnostic model may be the most fruitful for guiding technology interventions designed to reach vast numbers of individuals with both clinical and non-clinical reasons for desiring behavior change.

There are characteristics of interactive technology interventions that are currently known to influence their effectiveness. For example, we know that the following features of technology interventions are essential for behavior change: (1) self-monitoring of the desirable or problematic behavior of interest, such as diet, exercise, social activity; (2) providing individualized feedback to user inputs provided by programmed text or graphically, and occasionally delivered by a therapist dedicated to support of the tool; (3) social support provided by automated supportive and educational messages delivered via the program or by text messaging or email from a guide/therapist, and also sometimes provided via the availability of chat rooms and social media connections. Other key innovations could include leveraging social media to promote sociability and access to social resources to support and reinforce healthy behavior. We could also consider creative use of sensing technologies to measure activity levels, sociability, and depressive states (although their application to healthy aging has not been fully explored).

However, one problem that has dogged the digital health field is the challenge of adequately engaging the user. In face-to-face psychotherapy, the therapeutic alliance (i.e., the trust the client has in the therapist to bring about the behavioral changes they are seeking) has been shown to be the most important “non-specific” aspect of successful behavior change (Horvath, Del Re, Flückiger, & Symonds, 2011). Dropout rates for behavioral intervention technologies are high, at well over 50% (Richards & Richardson, 2012). One explanation for the high dropout rate may be the program’s inability to engage users and develop a therapeutic alliance with them, which may also negatively affect treatment effectiveness (Martin, Garske, & Davis, 2000; Ormrod, Kennedy, Scott, & Cavanagh, 2010; Zuroff et al., 2000). At the same time, this finding presents exciting opportunities for developing new methods for establishing alliance with health technology programs while evaluating their effects on behavior change, including personality trait change.

For example, in some of our own recent work we evaluated an interactive-media-based problem solving treatment program for depression (imbPST) designed to facilitate the development of the therapeutic alliance (Carter, Buckey, Greenhalgh, Holland, & Hegel, 2005). The imbPST program uses branching logic based on user inputs to guide hundreds of video and audio clips of a real therapist in order to simulate an actual therapy encounter. We compared imbPST to face-to-face therapy and another evidence-based internet therapy program for depression on the development of therapeutic alliance (Berman et al., 2014). At the end of therapy, imbPST was rated as equivalent to live therapy on a standardized measure of therapeutic alliance and was superior to the internet therapy program on this measure.

Still, there are challenges to developing highly interactive, tailored and engaging mHealth technologies. First, they are very expensive to produce, requiring the involvement of

multiple professionals including videographers, sound technicians, programmers, graphic artists, content experts and so on, and their respective equipment and space needs. Second, retaining the optimal immediacy and interactivity of interventions when delivered by mobile and internet technology requires strong bandwidth capabilities. Slow connectivity disrupts video and audio streaming which is essential for high fidelity presentation. The use of “relational objects” (computational artifacts of human beings) could possibly simplify some of the production barriers and show promising evidence for their ability to develop a strong therapeutic alliance with the program (Bickmore & Mauer, 2006). Another advantage of such a “virtual therapist” is that they could be easily modified to match user characteristics or preferences; e.g., age, race, gender, ethnicity, and spoken language, which may also promote alliance and efficacy.

Summary

Technology holds great promise for not only extending the reach of evidence-based interventions to improve healthy aging, but also adding to their effectiveness through the creative utilization of features unique to that technology delivery platform. These have yet to be applied to promoting healthy aging through personality development. However, we have promising therapeutic models (e.g., the transdiagnostic model) on which to base such interventions (e.g., the Unified Protocol for cognitive-behavioral therapy) and the technological expertise to develop engaging and highly interactive programs for their delivery. A particular advantage of technology-assisted interventions is their ubiquitous availability. They are not limited by time and space demands. They are available to users whenever they would like to access them. As such, they may ultimately be shown to be most effective when used in this flexible manner, like a personal coach or virtual therapist “in your pocket”, that is there when needed. This type of utilization could help to illuminate when changing behavioral patterns via technology-based therapeutic support tools crosses the threshold from a temporary psychological process/state supported by the technology to a level of automaticity to become a trait.

Challenges remain in both the logistics of designing and delivering the interventions and evaluating their effectiveness, as well as understanding the mechanisms through which they may exert their effects. Much work is also needed to design these technologies for easy access, use, and acceptability for the growing numbers and special needs of older adults. Success with addressing these challenges will require close collaboration between the communities of science and industry, but the potential benefits of such collaboration to the health of the population could be enormous.

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