A Scoped Review of the Potential for Supportive Virtual Coaches as Adjuncts to Self-guided Web-Based Interventions

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Abstract. This study aimed to explore supportive capabilities of VAs with the potential benefit in mind that users of self-guided eHealth interventions could be better supported. Spontaneous empathy and the explicitly expressed intention of *non-responsive VAs* to deliver user support is likely capable to engage and motivate users. *Responsive VAs* have even larger potential. However, they are more costly to realize and have a higher risk of failure. Effective user frustration detection and mitigation by Responsive VAs has been empirically demonstrated, but so far within artificial contexts. Altogether it makes sense to further explore the option to add VAs as adjuncts to self-guided eHealth interventions a potential remedy to low adherence.

Keywords: Virtual agent · Embodied conversational agent · Virtual human · Persuasive technology · ehealth

1 Introduction

Research [1] has suggested that Virtual Agents (VAs), taking on the role of coach or company on, have the potential to assist users of eLearning and eHealth solutions by engaging them. As self-guided eHealth interventions often face low adherence scores it is worthwhile to explore the motivational features and capabilities of VAs. Future self-guided eHealth interventions could potentially profit from VAs as adjuncts to engage and support users which could potentially offer a remedy to low adherence.

2 Methods

This study reviews and interprets the available literature on the potential of VAs by means of a scoped review. The rationale for choosing a Scoped Review is that the subject is broad, diverse and largely unexplored which warrants a scoped review methodology in which it is sought to present an overview of a such potentially large and diverse body of literature pertaining to a broad topic [2].

P.W. de Vries et al. (Eds.): PERSUASIVE 2017, LNCS 10171, pp. 43–54, 2017.
DOI: 10.1007/978-3-319-55134-0_4

2.1 Study Selection: Opportunities of Virtual Coaches to Deliver Support Within Web-Based Interventions for Health or Learning

The search aimed to create a generic idea of the capabilities of VAs (VAs) for supportive purposes. The Scopus and Web of Science databases were searched with a combination of the concepts 'VAs, 'web-based intervention', and 'support'. For each of the concepts, multiple key words were used. As VAs are often used within a e-learning context, it was decided to include studies on Intelligent Tutoring Systems (ITS) as well.

Inclusion criteria were:

- Papers had to address VAs interacting with users

Exclusion criteria were:

- Papers that solely focused on the effects of VAs in Virtual Reality.
- Papers that described computer simulations with agents/during which interaction between human users and VAs were absent

The systematic search resulted in a limited number of studies (8). Moreover, these studies addressed a wide range of topics; from physical attributes [3], architecture [4], route planning [5], non-verbal behavior [6], virtual museum guide [7], empathy [8], to theoretical models [9] and articulation rates [10]. None of the studies provided a high-level picture of the capabilities of VAs with regards to support delivery. Therefore it was decided to expand the number of articles by means of hand search. We started the hand search by checking references within the 8 articles and searching on terms found within the 8 articles in Google Scholar.

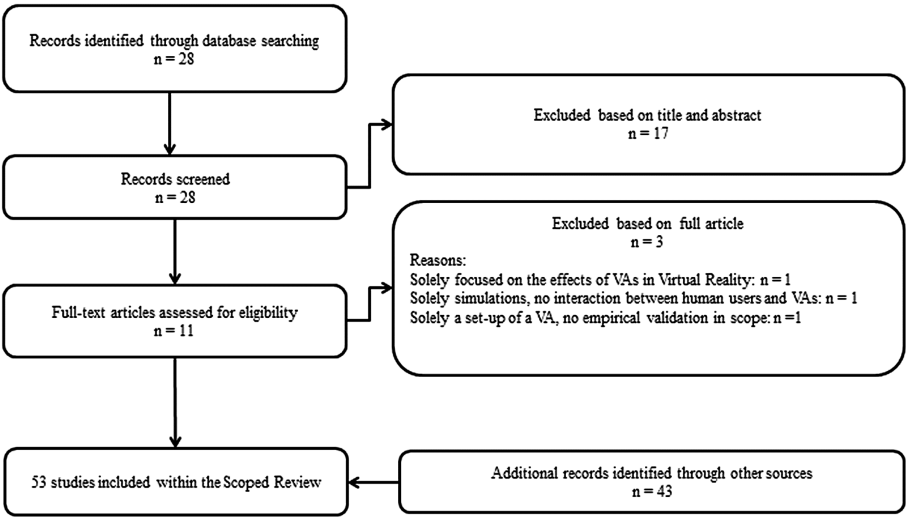

Fig. 1. Flow diagram of the study selection of the scoped review

The hand search had the following aims:

(a) Finding synthesizing information on VAs within a health or pedagogical context with a focus on the delivery of support and motivating users. We started with the information found in [8] and additionally searched for meta studies on VAs.
(b) Finding additional (founding) articles on the CASA effect as mentioned within [3, 8].
(c) Finding addition information on relationship building [10] and measures of relationship building as shortly described in [6, 10].
(d) Finding additional information on theoretical models related to VAs as touched upon in [9].

The search procedure resulted in **53** included articles (see Fig. 1 below)

2.2 Data Extraction

Studies were analyzed and the various VA aspects were categorized within themes. The themes were chosen as a means to provide insight in the various aspects of VAs that relate to user motivation. Secondly, the themes served to aggregate information that was distributed over different articles found. For an overview of the articles included.

2.3 Results

Table 1 shows the themes that were found in the included studies. Below Table 1 these themes are further described.

Theme 1: Computers as Social Actors (CASA). A large body of studies on VAs refer to the CASA effect [13, 15] as a cornerstone for studying human-computer interactions and especially human-VA interactions. The CASA effect demonstrates that humans treat media – in some respect- in the same way as they treat other humans. Various manifestations of this effect have been described such as:

- Computers that display flattery texts towards their users are preferred by their users compared to computers that do not display such texts
- Computers that textually praise other computers are better liked than computers that praise themselves, and computers that 'criticize' other computers are disliked compared to computers that criticize themselves
- Users who are partnered with an computer on basis of a color (e.g. the blue team) will have a more positive opinion on the computer and cooperate more with it than users who have to partner with a computer of the opposite, differently colored team

As an explanation of the CASA effect, it has been proposed that humans have a strong innate tendency to make social connections with other humans and other living creatures such as pets. This human tendency becomes real when objects such as personal computers demonstrate activities that could be socially interpreted by their users [15]. Although pc's can act socially, human users are logically aware of their non-social and non-living status. This seems a paradox: why would a human user socially respond to a pc while at the same time realizing that a pc does not warrant it? Nass and Moon [12]

Table 1. Table 1 Themes and articles for supportive VAs.

Theme	Explanation	Sources
1. Computers As Social Actors (CASA)	Humans treat media in the same way as they treat other humans	Systematic search: [8] Hand Search: [11–15]
2. Open dialogue between user and computer	VAs have the ability to have an open verbal dialogue with users	Systematic search: [7] Hand Search: [14–16]
3. Visible conversation partner	Interaction with a 'talking face' leads to more trust and believability.	Systematic search: [3, 5, 8, 9] Hand Search: [19, 23]
4. Human-Computer relationship	Interactions with an agent can lead to a relationship, which is important to keep users engaged over time	Systematic search: [10] Hand Search: [1, 24–30]
5. Measures of the Human-Computer relationship	Human-VA relationship quality can be measured	Systematic search: [6] Hand Search: [1, 22, 32, 37]
6. Responsive verbal and non-verbal communication	Computers should have the ability to notice and respond to verbally and non-verbally expressed emotions from their user, in order to create a more natural interaction	Systematic search: [8] Hand Search: [27, 31–38]
7. Impact of VAs on User motivation	There is evidence that VAs can motivate users, which is highly dependent on VA implementation, context, task etc	Systematic search: [4] Hand Search: [21, 38, 42–46]
8. Methodological issues within VA research	Most experiments into VAs face similar methodological issues which have to be taken into account when interpreting the research	Hand Search: [45–49]

refer to 'mindless' (automatic, largely unaware) human behavior that the machine can trigger. This mindless behavior will be displayed as long as it remains socially acceptable. This phenomenon is also associated with the notion of 'suspension of disbelief', meaning that up to a certain point humans are willing to apply social rules to non-human yet communicative objects, irrespective of their non-living status.

Theme 2: Open Dialogue between user and computer. A following theme is the ability of computers and VAs to have an open verbal (textual or speech) dialogue with users. Within regular, day to day Human-Computer Interaction events, a user who interacts with their IT system will typically activate pre-defined menu options such as the 'save as' option within Microsoft Word. Subsequently, the computer will respond to the request by presenting a pop-up window which will enable the user to type in the file

name of the document. In such a closed dialogue scenario, the interactions between user and software traditionally have a task-specific character (e.g. serve to reach a specific goal such as saving a document), have a short duration and are typically initiated by the user (and not by the computer). In contrast, VAs enable more open-ended and more relationship-oriented interactions. Interactions between VAs and users can span multiple question and answer pairs and can therefore be interpreted as a dialogue. The ELIZA study [18] described an early version of a textual psychotherapists that gave 'canned' responses to user questions as a result of quickly processing the input text provided and create a response out of it without realizing what the user had said (e.g. a question like: "Eliza, I feel miserable today" and an answer: "How often do you experience feelings of being miserable?"). Later studies create richer dialogue contexts to explore the capabilities of computers interacting with humans. Examples are first a study that has shown that a robot taking the role of museum guide who uses e.g. empathy and humor in his conversation style led to a more positive attitude towards the robot than the same robot without this enhanced conversation style [7]. A second study showed that a VA with high dialog capabilities reached more accurate answers when interviewing a subject than an agent with less dialog capabilities [16]. A third study [17] aimed to explore where open-dialogue options between users and VAs would lead to. The authors report that when learners are given opportunities to guide an open conversation, they especially ask off-topic questions. For example, learners often want to know about the agents' operating systems, design, purpose, and capabilities. Such conversations seem to serve the 'testing' of agents' abilities during which learners are attempting to discover the boundaries, limits, and capabilities of agents through 'game-like' inquiry.

Theme 3: Visible conversational partner. The following theme is the visibility of the conversational computer depicted as a (either static or animated) human face. According to Lisetti [24] the human face has a special status in human to human communication as it has often been identified as the most important channel for conducting trust and believability. As Lisetti states, the face as a communication channel has a higher status than bodily regions such as posture and gesture [20]. Multiple studies have supported this notion by demonstrating that users preferred to interact with a 'talking face' instead of a text only interface [28], an anthropomorphic agent together with a human voice has led to greater agent credibility [19], visible agents have led to greater positive motivational outcomes [27] and task performance [29].

Theoretical support for a visible, human-like personal computer is provided by the Social Agency Theory [25] and Social Modelling/Social Learning Theory Jordine et al. [3, 9]. Nonetheless the visibility subject is somewhat controversial. Strong claims against the human face are provided by Norman [14] by his statement that a human face triggers false mental models and thus creates wrong user expectations. Other critique is provided by Rajan et al. [26] who demonstrated that it is first and foremost the voice (and not the visibility of the VA) that is responsible for positive learning effects. Mayer [25] criticizes the benefits of a visible, but static human face on screen. What is important for learning according to Mayer is the level of animation of the VA, which makes the agent engaging to the user.

Theme 4: Human-VA Relationship. A fourth theme is the concept that regular human-computer interaction events result in a relationship. Routine interactions between a user and their computer should be regarded as contributions to this human-computer relationship, as is argued by Bickmore et al. [1]. Although this relationship may be implicit, it has an impact on the user. The relationship plays a role even in case no relationship skills (e.g. empathy, humor) have been designed and built into the machine.

The question arises whether a VA with a relationship-focused design could behave and be perceived as a competent social actor. This quality of the VA as a conversational partner is impacted by:

- Interaction duration. As described by Krämer et al. [35] getting people engaged with VAs is easy, but keeping then engaged over time is much more challenging. Bickmore et al. [1] (on physical activity) and Creed et al. [31] (on fruit consumption) conducted emotional virtual coach studies that spanned more than 28 days. They both found that deploying the emotional VA did not result in user behavior changes, but that users in general preferred to interact with the emotional virtual coaches.
- Natural vs forced interaction. Gulz [33] suggests that most VAs studies force the human-computer relationship too much. Users have no other option than to interact with the VAs they are confronted with.
- User personality. Von der Pütten et al. [36] make clear that it depends on the personality of the user how the human-computer relationship will develop. They demonstrated that 5 user personality factors were better predictors for the evaluation outcome of VAs than the actual behavior of the VA.

Theme 5: Measures of the Human-VA Relationship. The literature found mentions two regular measures with regards to the Human-VA Relationship.

- Measure 1: Working Alliance

Working Alliance is a construct that originates from the psychotherapy literature and has been described as "the trust and belief that the helper and patient have in each other as team-member in achieving a desired outcome" [37]. Bickmore et al. [30] applied the working alliance inventory in their 30-day longitudinal study with a VA acting as an exercise coach. Participants who interacted with a VA with relational behavior enabled (empathy, social chat, form of address, etc.) scored the VA significantly higher on the Working Alliance Inventory compared to participants who interacted with the same VA with the relational behaviors disabled.

- Measure 2: Rapport

A second important human-computer relationship measure is rapport. Rapport has been described as "the establishment of a positive relationship among interaction partners by rapidly detecting and responding to each other's nonverbal behavior" [32]. Measurement of rapport has been conducted by Gratch et al. [32] in their evaluative VA study. Their results showed that the experience of rapport was of a comparable level compared to a face-to-face (i.e. human interlocutor) condition.

Theme 6: Responsive verbal and non-verbal communication. Within human to human communication, the exchange of non-verbal information plays a key role. Social psychologists assert that more than 65% of the information exchanged during a person-to-person conversation is conveyed through the non-verbal band [39, 45]. The non-verbal channel is said to be especially important to communicate socio-emotional information. Socio-emotional content [40] is vital for building trust and productive human relationships that go beyond the purely factual and task-oriented communication. D'Mello et al. [40] describe the mutual impact of user and (synthetic) computer emotions as an affective loop which is pictured as follows:

- The user first expresses their emotion through verbal and physical interaction with the machine, e.g. through detectable gestures, usage of the keyboard or spoken language
- Then, the system responds by generating affective responses, through words, speech, animation and theoretically also colors and haptics
- This response affects the user in such a way that they become more involved in their further interaction with the computer

Concerning the importance of the affective loop, there are two stances:

- Stance 1: Responsiveness of VAs (affective loop) is a critical condition for prolonged user interaction. Doirado et al. [42] confirm the importance of the affective loop mechanism and state that a VA that lacks the capacity to understand the user and the capability to adapt its behavior (a non-responsive VA) will break the user's suspension of disbelief.
- Stance 2: Autonomy of VAs (no affective loop) is a sufficient condition for prolonged user interaction. Rosenberg-Kima et al. [27] deployed an autonomous (i.e. non-responsive) VA that introduced itself and provided a twenty-minute narrative about four female engineers, followed by five benefits of engineering careers. The VA was animated and its voice and lip movements were synchronized. The VA acted autonomously; interaction between participants and VA was purely restricted to the user clicking on the button for text topic. The results showed that the self-efficacy of the users and of their interest in the subject presented was significantly higher within the VA + voice condition compared to the voice-only condition. In support of these results, Baylor et al. [19] state that people are willing to interact with anthropomorphic agents even when their functionality is limited. As she indicates the mere visual presence and appearance will in some contexts be the determining factor and not so much its supportive, conversational or animation capabilities.

Theme 7: Impact of VAs on user motivation. Meta-studies and reviews [33, 45, 49, 50, 53] have reported on claims and evidence for positive VAs effects on learning, engagement and motivation. Schroeder et al. reviewed 43 studies and conclude that pedagogical agents have a small but significant effect on learning as ultimate outcome. Within their study, Schroeder et al. [45] did not make a distinction between responsive and non-responsive VAs. Specific research with regard to motivating users has also been conducted by deploying responsive VAs with the task to notice user frustration and empathically respond to it. Autonomous delivery of warmth and empathy by VAs

towards users has shown positive effects, and studies show that this effect may be larger at the time the user experiences frustration [38, 50].

All together the evidence for VAs that are capable of motivating users is mixed and inconclusive. VAs, whether they are non-responsive or responsive, provide a positive user experience as a result of their entertainment capabilities. Responsive VAs when specifically designed to detect user frustration and to empathically respond to it, have also empirically demonstrated positive effects on user attitudes. However, these positive effects have not yet been found in ecologically valid context but only within constrained contexts such as games with clear win and lose rules and as a result of system-generated moments of user frustration.

Theme 8: Methodological issues within VA research. The inconclusiveness regarding VA evidence as mentioned within the previous theme is claimed to be caused by methodological issues [50, 53]. Methodological issues make it difficult to compare study results and to draw generic conclusions. One of those issues is the difference in set-ups amongst VA studies. To name a few:

- Different modalities used for output: (synthesized or natural) speech or text
- Different levels of responsive emotional behavior; from textual responses projected alongside a static VA to fine-grained VA facial expressions intended to mirror the user's facial expressions
- Different roles: tutor, peer, interviewer, coach
- Different implementations/different computer code applied as Artificial Intelligence to steer the VA with code based on different behavioral theories

Many of these issues can be resolved by using a common, open research platform for VAs, such as the Virtual Human platform as provided by USCT [51]. Other issues can potentially be resolved by a common design framework for VAs as proposed by Veletsianos et al. with their EnALI framework [52].

Concerning the duration of the change programs several studies (e.g. [30, 31]) stress that the majority of virtual coaching studies concern short time spans of minutes or hours, which makes it difficult to study the development of the human-computer relationship and to realize effects on user behavior. Both Bickmore et al. and Creed et al. ([30, 31]) conducted emotional virtual coach studies that spanned more than 28 days. They both found that deploying the emotional VA did not result in user behavior changes, but that users in general preferred to interact with the emotional virtual coaches. Altogether Dehn and van Mulken [50] summarize the situation as follows: "… the simple question as to whether an animated interface improves human-computer interaction does not appear to be the appropriate question to ask. Rather, the question to ask is: what kind of animated agent used in what kind of domain influence what aspects of the user's attitudes or performance".

3 Conclusions and Discussion

This Scoped Review aimed to give insight into the potential of VAs to deliver effective related support to humans.

On a high level, the following two kinds of VAs were distinguished:

- *Non-responsive (autonomous) VAs*. These VAs are not endowed with senses to 'see' or 'hear' the verbal or non-verbal signals that the user expresses, and logically also lack the capacity to interpret these signals and respond to them. Instead, the VA is visually present to send out motivational messages intended to keep the spirits up, irrespective of how the user feels or what he does. Pro: these kinds of VAs have demonstrated that they can engage users. Con: forced presence of the VA runs the risk of annoying the user and can therefore become counter-productive. As a solution to keep the benefits and mitigate the drawbacks, users should be given control over the presence of the non-responsive VA.
- *Responsive VAs*. These VAs have the capability to capture and analyze the verbal and/or non-verbal signals sent by the user and emotionally respond to them. These VAs are set up with the intention to understand the user and to adapt their behavior accordingly. Pro: these VAs can tap into the rich sources of verbal and non-verbal information as spontaneously and freely provided by humans. This emotion-related information is key for human to human communication and it therefore makes sense to find ways to use this kind of information for productive HCI. Con: realizing a VA that does understand the user is a heavy task, requiring costly computational modeling of user BDI (Believe, Desire and Intentions) and affective loop facilities with a high chance of failure.

Altogether it makes sense to further explore the option to add VAs as adjuncts to self-guided eHealth interventions a potential remedy to low adherence. For preventing complex and costly experimental set-ups, it is advisable to start further experimentation with non-responsive VAs.

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