Are Conversational Agents Used at Scale by Companies Offering Digital Health Services for the Management and Prevention of Diabetes?

Roman Keller[1][a], Jiali Yao[1][b], Gisbert Wilhelm Teepe[2][c], Sven Hartmann[5][d], Kim-Morgaine Lohse[2], Florian von Wangenheim[1,2][e], Falk Müller-Riemenschneider[1,3,4][f], Jacqueline Louise Mair[1,2,*][g] and Tobias Kowatsch[1,2,5,*][h]

[1]*Future Health Technologies, Singapore-ETH Centre, Campus for Research Excellence and Technological Enterprise (CREATE), Singapore*

[2]*Center for Digital Health Interventions, Department of Management, Technology, and Economics, ETH Zurich, Zurich, Switzerland*

[3]*Saw Swee Hock School of Public Health National University of Singapore, Singapore*

[4]*Yong Loo Lin School of Medicine, National University of Singapore, Singapore*

[5]*Centre for Digital Health Interventions, Institute of Technology Management, University of St. Gallen, St. Gallen, Switzerland*

roman.keller@sec.ethz.ch

Keywords: Digital Health Companies, Healthcare, Type 2 Diabetes, Prevention, Management, Funding, Conversational Agents.

Abstract: Successful interventions to prevent and manage type 2 diabetes rely on long-term, day-to-day decisions which take place outside of clinical settings. In this context, human resources are difficult to scale up, and leveraging Conversational agents (CAs) could be one way to scale up healthcare to tackle the emerging epidemic of type 2 diabetes. The objective of this paper is to assess the degree to which CAs are employed by top-funded digital health companies that target the prevention and management of type 2 diabetes. Companies were identified via two venture capital databases, i.e. Crunchbase Pro and Pitchbook. Two independent reviewers screened results and the final list of companies was validated and revised by three independent digital health experts. The companies' digital services (usually mobile applications) were accessed and reviewed for the utilisation of CAs. To better understand the purpose of identified CAs, relevant publications were identified via PubMed, Google Scholar, ACM Digital Library and on the companies' website. Nine out of 15 companies' digital services were accessible to the authors and only in one case a CA was employed. The uptake of CAs by top-funded digital health companies targeting type-2 diabetes is still low.

1 INTRODUCTION

Diabetes is a chronic condition characterized by elevated levels of blood glucose. It occurs when the pancreas cannot produce sufficient hormone insulin or the body cannot use the insulin effectively (WHO, 2016). If not managed appropriately, diabetes can lead to a series of life-threatening microvascular and macrovascular complications including blindness,

[a] https://orcid.org/0000-0003-4810-4944
[b] https://orcid.org/0000-0001-7269-4679
[c] https://orcid.org/0000-0002-2264-9797
[d] https://orcid.org/0000-0002-0256-6687
[e] https://orcid.org/0000-0003-3964-2353
[f] https://orcid.org/0000-0003-1402-7477
[g] https://orcid.org/0000-0002-1466-8680
[h] https://orcid.org/0000-0001-5939-4145
*Shared last authorship

Keller, R., Yao, J., Teepe, G., Hartmann, S., Lohse, K-M., von Wangenheim, F., Müller-Riemenschneider, F., Mair, J. and Kowatsch, T.
Are Conversational Agents Used at Scale by Companies Offering Digital Health Services for the Management and Prevention of Diabetes?.
In *Proceedings of the 14th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2021) - Volume 5: HEALTHINF*, pages 811-816
ISBN: 978-989-758-490-9 ISSN: 2184-4305

kidney failure, heart attacks, stroke and lower limb amputation (WHO, 2016).

Type 2 diabetes (T2D) is the most common form of diabetes and accounts for about 90% of diabetes cases worldwide (International Diabetes Federation, 2019; WHO, 2016). Despite its links to non-modifiable factors such as family history, ethnicity, and increasing age, T2D is strongly tied to key modifiable lifestyle risk factors including overweight or obesity, poor diet, physical inactivity, and smoking (International Diabetes Federation, 2019; WHO, 2016). Numerous landmark studies in the past have demonstrated that over 50% of T2D can be prevented or delayed through cornerstone interventions targeting lifestyle modification and through pharmacological interventions (International Diabetes Federation, 2019). Likewise, strong evidence also shows that T2D can be effectively managed, or even reversed, in T2D patients via similar intervention strategies (International Diabetes Federation, 2019). Despite firm and encouraging evidence, many key challenges persist with respect to real-world implementation of T2D prevention and management interventions at scale. One key challenge is that conventional approaches of delivering these T2D interventions are financially expensive and human-resource intensive (Wu et al., 2019). Another is that these interventions on T2D, similar to those on other non-communicable diseases, rely heavily on individual's long-term and day-to-day decisions, which mostly occur outside clinics and hospitals and are difficult to monitor and intervene in traditional manners (Rui et al., 2014; Wu et al., 2019).

Rapid advancements in digital and wireless technology have provided unprecedented opportunities to overcome such challenges and transform and 'scale-up' healthcare delivery. This has motivated large amounts of recent research and investments of digital health companies into developing digital solutions (Kvedar et al., 2016), aiming to harness pervasive digital technology to improve and scale up the prevention and management of T2D (Alexander Fleming et al., 2020). Promising results have been found in many digital programs of T2D on glucose control, medication adherence, weight loss, and quality of life (Alexander Fleming et al., 2020). However, digital health programs have so far been hampered by low user engagement and high attrition rates, and long-term evidence is lacking to comprehensively assess practical values (Garg & Parkin, 2019). To address these issues, 'virtual diabetes coaching' via Conversational Agents (CAs) has been identified as an encouraging component of current and future digital health offering for T2D care (Garg & Parkin, 2019; O'brien, 2017; Ramchandani, 2019).

CAs are computer systems that imitate human conversation using images, text or spoken language and they can offer personalized human-like interactions and social contacts (Laranjo et al., 2018; Schachner et al., 2020). Recent studies have shown promising results of CAs with regard to patient satisfaction (T. W. Bickmore et al., 2010), treatment outcomes (Ma et al., 2019), and the ability to build work alliances with the patient (T. W. Bickmore & Picard, 2005; Hauser-Ulrich et al., 2020; Kowatsch et al., 2020). In addition, CAs have been found to be safe for T2D care and even provide comparable effectiveness to peer human coaching (Car et al., 2020; King et al., 2020).

However, despite an increasing evidence base of utilizing CAs for T2D prevention and management, little is known about the actual adoption of CAs in the burgeoning digital health industry and its most successful companies. Moreover, there is a need to identify the characteristics of those CAs in order to guide future developments in the industry. Therefore, this study aims to provide an observational analysis of the uptake and characteristics of CAs among digital services of the top-funded companies in the T2D digital health industry.

2 METHODS

2.1 Databases and Companies

Top-funded digital health companies targeting the prevention and management of T2D were identified using the two venture capital databases Crunchbase Pro and Pitchbook (Crunchbase, n.d.; PitchBook, n.d.). These databases have been found to be among the most comprehensive and accurate venture capital databases and both are commonly used in academic reports and by investors (Retterath & Braun, 2020). We decided to select the fifteen companies with the most funding in terms of total funding amount through July 23, 2020.

2.1.1 Search Strategy

The search strategy included an extensive list of terms describing the constructs "verticals & methods & industries", "diabetes", and "management & prevention". The overview of the complete search strategy for Crunchbase and Pitchbook is shown in Table 1.

Table 1: The search strategy used in Crunchbase and Pitchbook.

Search category	Search terms
Verticals & methods & industries	Monitoring Equipment OR diagnostic OR HealthTech OR healthcare devices OR connected health* OR Therapeutic Devices OR Digital Health OR digital health* OR health* technology OR health* app* OR wearables OR Mobile health OR mhealth OR mobile app OR personal health OR virtual care OR e-health OR assistive technology OR telehealth OR telemedicine OR health* platform OR healthcare it OR data management OR Artificial Intelligence & Machine Learning OR Cloud data services OR analytics OR health* diagnostics OR Big Data OR information OR digital OR data OR biometrics OR home health care OR medtech OR self-monitoring
Diabetes	obesity OR blood sugar OR blood glucose OR insulin OR diabet*
Management & Prevention	diabetes management OR diabetes treatment OR diabetes control OR diabetes monitoring OR blood sugar monitoring OR disease monitoring OR disease management OR risk reduction OR disease prevention OR diabetes prevention OR prevention OR prediabet*

2.1.2 Selection Criteria

We included companies if they offered a digital health intervention that involved the prevention or management of T2D. A digital health intervention was defined as a discrete functionality of digital technology that is applied to achieve health objectives and followed the definition of the WHO classification of digital health interventions (World Health Organization, 2018).

Companies were excluded if their intervention (1) did not focus on patients; (2) mainly focused on the administrational needs of hospitals (hospital information systems); and (3) did not involve a digital solution as main intervention component. In addition, we excluded companies if their intervention (4) involved any form of continuous blood glucose monitoring or automated insulin delivery system; (5) did not involve behaviour change; and (6) mainly targeted insulin-dependent diabetics, as such interventions mainly target medication adherence rather than lifestyle behaviours.

Furthermore, we excluded companies in which the intervention was any kind of general weight loss or fitness app without focus on T2D.

2.1.3 Selection Process

The top 15 most-funded companies combined from both database searches were identified as they account for over 90% of the total funding in all companies which gives a representative and comprehensive insight into current state of the digital health industry. In case of conflicting funding information between both databases, Crunchbase information was preferred as it has been found to have better coverage with respect to total capital committed and financing rounds than Pitchbook (Retterath & Braun, 2020). Eligibility of companies was determined by two independent investigators. The results were compared, and disagreements discussed until a consensus was reached.

After a first list was defined, three independent experts in the fields of digital health and T2D were approached to validate the company list. In case of disagreements between experts, the authors followed the opinions of the majority. Based on their feedback, the company selection criteria were slightly adapted, and the company list was adapted. In particular, companies that provide interventions for continuous glucose measurement and automated insulin delivery systems were excluded from our list, as their digital solution was not considered to be the main intervention component. In addition, the services of those companies mainly focused on insulin-dependent diabetics and were not involving any behavioural change strategies. Furthermore, the company KKT Technology Pte. Ltd. (Holmusk) was added to the list of top-funded digital health companies, as the company meets our inclusion criteria in terms of the amount of funding and offered digital health intervention but was not identified with our search strategy.

2.2 Digital Health Interventions

All identified digital services were available in the form of mobile applications as predominant mode of intervention delivery. Thus, we searched and downloaded these apps from the two most popular app stores: Google Play store and Apple app store (IDC, 2020). The latest app search was conducted on November 21, 2020.

If a mobile application was not accessible to the authors, the companies were systematically approached via email and requested for access. In

case no reply was received on the first email, a follow-up email was sent two weeks later.

If the authors were not able to access the app, no judgement on the presence of a CA could be done.

2.3 Publications

Three databases (PubMed, Google Scholar, and ACM Digital Library) were systematically searched for scientific articles, published between database inception and October 2020, using the search terms *"Name_Intervention" AND (Smartphone OR Application OR App OR Intervention OR Mobile Health)* relating to the identified company's T2D app. In addition, we screened the websites of the companies for relevant publications on their conversational agents, as some publications could not be identified via the databases searches.

2.4 Conversational Agents

Two investigators reviewed the identified accessible apps and assessed whether a conversational agent was utilised (Table 2). In a second step, the characteristics of the identified CA were extracted by reviewing the app as well as the identified publications. The conversational agent characteristics included the health goal, type of agent, input format, output format and dialogue initiative. Covidence (www.covidence.org) was used for the data extraction.

3 RESULTS

The overview of the 15 top-funded digital health companies in the prevention and management of T2D and their utilised CAs can be seen in Table 2.

From the reviewed companies, 6 apps were not accessible because they were only available: (1) with a subscription service (Virta Health Corp., Dario Health Corp.); (2) in a specific geographic region (Virta Health Corp., Welldoc Inc., Liva Healthcare ApS); or (3) with an employer subscription or when being referred by a physician (Virta Health Corp., Dario Health Corp., Welldoc Inc., Twin Health Inc., Sweetch Health Ltd.). Of the 9 accessible apps, 8 apps did not include any CAs, and Lark Technologies, Inc. was the only company with an app that employed a conversational agent.

As Lark Technologies, Inc. was the only company with a diabetes-relevant conversational agent, only publications of Lark Technologies, Inc. were considered for this analysis.

Table 2: Ranking of the fifteen top-funded digital health companies in type 2 diabetes prevention and management and utilisation of CAs in the mobile applications of the companies as of November 27, 2020, sorted in descending order of total funding amount. CA = Conversational agent, Y = CA used, N = No CA used, - = Mobile application not accessible.

Company Funding Rank #	Company legal name	CA used?
1	Omada Health, Inc.	N
2	Livongo Health, Inc.	N
3	Virta Health Corp.	-
4	Noom, Inc.	N
5	DarioHealth Corp.	-
6	Informed Data Systems, Inc. (One Drop)	N
7	Lark Technologies, Inc.	Y
8	Vida Health, Inc.	N
9	Welldoc, Inc.	-
10	Twin Health, Inc.	-
11	Oviva, Inc.	N
12	KKT Technology Pte. Ltd. (Holmusk)	N
13	Fruit Street Health P.B.C.	N
14	Sweetch Health Ltd.	-
15	Liva Healthcare ApS	-

Lark Technologies, Inc. offers a digital care platform for chronic conditions and has specialised health plans for patients with diabetes, hypertension, prediabetes and general health risk behaviours such as stress and anxiety, smoking cessation or weight management. Lark is accessible to all users via their employer, health plan, provider or individually through a subscription. A basic version of the app is free and available to everyone.

Two publications of Lark Technologies, Inc. were identified via the company website and both papers were not published in peer-reviewed journals (Stein et al., 2019, 2020).

The goals of Lark's conversational agent comprised assistance, training, education, prevention and onboarding. It utilized a counselling type of agent with a mixed dialogue initiative (system and user were both able to start a conversation). The input format allowed for fixed text with predefined answer options and external input from sensors (E.g. smartphone accelerometer, location sensor). The output format was only in text.

4 DISCUSSION

To our knowledge, this is the first study to identify the degree to which the most successful companies offering digital health interventions for the prevention and management of T2D employ CAs. Our study found that out of nine accessible diabetes apps, only in one case, a CA is used. This indicates that the T2D industry uptake of CAs still remains low.

This finding corroborates recent research findings of literature reviews investigating the state of research on CAs in healthcare which is still considered to be in an early developing stage (Bérubé et al., 2020; Car et al., 2020; Laranjo et al., 2018; Montenegro et al., 2019; Schachner et al., 2020). With specific focus on T2D, most reviews only identified a small number of CAs targeting T2D. For example, a scoping review by Car et al. only identified two studies involving a conversational agent to target T2D prevention or management (Car et al., 2020). Interestingly, one of the identified studies by Car et al. (Car et al., 2020) assessed a digital health intervention from Wellthy (Wellthy Therapeutics Private Limited) which would have been a relevant company for our study (Sosale et al., 2018). However, due to insufficient funding Wellthy did not appear on our list of the top-funded digital health companies targeting T2D. This shows that our approach to only focus on the top funded companies may have left out certain relevant companies that employ CAs for T2D management or prevention.

Nonetheless, the general lack of CAs in the identified digital health interventions is remarkable. One potential reason for the low utilisation of CAs could be safety concerns for patients and consumers when relying on actionable medical information from CAs (T. W. Bickmore et al., 2018).

The low utilisation of CAs could limit the interventions' scalability as traditional nondigital approaches are generally time and resource intensive. For example, the use of human health experts is expensive, and it requires considerable time resources from experts to provide personalised lifestyle coaching to each intervention user. In addition, CAs have recently shown promising results related to patient acceptance (T. W. Bickmore et al., 2010) and on building work alliances with patients (T. Bickmore et al., 2005). Therefore, we advise digital health companies to increasingly consider CAs in their digital health interventions for the prevention and management of T2D.

5 CONCLUSIONS

The use of CAs in digital health interventions of top-funded digital health companies targeting the prevention and management of T2D still remains low. Digital Health companies should increasingly consider the use of CAs in their interventions to increase scalability by reducing costs and time resources.

ACKNOWLEDGEMENTS

This research is supported by the National Research Foundation, Prime Minister's Office, Singapore under its Campus for Research Excellence and Technological Enterprise (CREATE) programme.

REFERENCES

Alexander Fleming, G., Petrie, J. R., Bergenstal, R. M., Holl, R. W., Peters, A. L., & Heinemann, L. (2020). Diabetes digital app technology: Benefits, challenges, and recommendations. A consensus report by the European Association for the Study of Diabetes (EASD) and the American Diabetes Association (ADA) Diabetes Technology Working Group. *Diabetes Care*, *43*(1), 250–260. https://doi.org/10.2337/dci19-0062

Bérubé, C., Schachner, T., Keller, R., Fleisch, E., von Wangenheim, F., Barata, F., & Kowatsch, T. (2020). Voice-based Conversational Agents for the Prevention and Management of Chronic and Mental Conditions: A Systematic Literature Review. *JMIR Preprints 30/11/2020:25933*. https://doi.org/10.2196/preprints.25933

Bickmore, T., Gruber, A., & Picard, R. (2005). Establishing the computer-patient working alliance in automated health behavior change interventions. *Patient Education and Counseling*, *59*(1), 21–30. https://doi.org/10.1016/j.pec.2004.09.008

Bickmore, T. W., Mitchell, S. E., Jack, B. W., Paasche-Orlow, M. K., Pfeifer, L. M., & O'Donnell, J. (2010). Response to a relational agent by hospital patients with depressive symptoms. *Interacting with Computers*, *22*(4), 289–298. https://doi.org/10.1016/j.intcom.2009.12.001

Bickmore, T. W., & Picard, R. W. (2005). Establishing and maintaining long-term human-computer relationships. *ACM Transactions on Computer-Human Interaction*, *12*(2), 293–327. https://doi.org/10.1145/1067860.1067867

Bickmore, T. W., Trinh, H., Olafsson, S., O'Leary, T. K., Asadi, R., Rickles, N. M., & Cruz, R. (2018). Patient and consumer safety risks when using conversational assistants for medical information: An observational

study of siri, alexa, and google assistant. *Journal of Medical Internet Research*, *20*(9), e11510. https://doi.org/10.2196/11510

Car, L. T., Dhinagaran, D. A., Kyaw, B. M., Kowatsch, T., Joty, S., Theng, Y. L., & Atun, R. (2020). Conversational agents in health care: Scoping review and conceptual analysis. In *Journal of Medical Internet Research* (Vol. 22, Issue 8, p. e17158). JMIR Publications. https://doi.org/10.2196/17158

Crunchbase. (n.d.). *Crunchbase [home page on the internet]*. Retrieved November 29, 2020, from https://www.crunchbase.com/

Garg, S. K., & Parkin, C. G. (2019). The Emerging Role of Telemedicine and Mobile Health Technologies in Improving Diabetes Care. *Diabetes Technology and Therapeutics*, *21*(S2), S2-1-S2-3. https://doi.org/10.1089/dia.2019.0090

Hauser-Ulrich, S., Künzli, H., Meier-Peterhans, D., & Kowatsch, T. (2020). A smartphone-based health care chatbot to promote self-management of chronic pain (SELMA): Pilot randomized controlled trial. *JMIR MHealth and UHealth*, *8*(4), e15806. https://doi.org/10.2196/15806

IDC. (2020). *Introduction - WHO guideline Recommendations on Digital Interventions for Health System Strengthening - NCBI Bookshelf*. https://www.ncbi.nlm.nih.gov/books/NBK541905/

International Diabetes Federation. (2019). *IDF Diabetes Atlas 9th edition*.

King, A. C., Campero, M. I., Sheats, J. L., Castro Sweet, C. M., Hauser, M. E., Garcia, D., Chazaro, A., Blanco, G., Banda, J., Ahn, D. K., Fernandez, J., & Bickmore, T. (2020). Effects of counseling by peer human advisors vs computers to increase walking in underserved populations: The COMPASS randomized clinical trial. *JAMA Internal Medicine*, *180*(11), 1481–1490. https://doi.org/10.1001/jamainternmed.2020.4143

Kowatsch, T., Schachner, T., Harperink, S., Barata, F., Dittler, U., Xiao, G., Stanger, C., von Wangenheim, F., Fleisch, E., Oswald, H., & Möller, A. (2020). Conversational Agents as Mediating Social Actors in Chronic Disease Management Involving Healthcare Professionals, Patients, and Family Members. *JMIR Preprints #25060*. https://preprints.jmir.org/preprint/25060

Kvedar, J. C., Fogel, A. L., Elenko, E., & Zohar, D. (2016). Digital medicine's march on chronic disease. *Nature Biotechnology*, *34*(3), 239–246. https://doi.org/10.1038/nbt.3495

Laranjo, L., Dunn, A. G., Tong, H. L., Kocaballi, A. B., Chen, J., Bashir, R., Surian, D., Gallego, B., Magrabi, F., Lau, A. Y. S., & Coiera, E. (2018). Conversational agents in healthcare: A systematic review. In *Journal of the American Medical Informatics Association* (Vol. 25, Issue 9, pp. 1248–1258). Oxford University Press. https://doi.org/10.1093/jamia/ocy072

Ma, T., Chattopadhyay, D., & Sharifi, H. (2019). Virtual humans in health-related interventions: A meta-analysis. *Conference on Human Factors in Computing Systems - Proceedings*, 1–6. https://doi.org/10.1145/3290607.3312853

Montenegro, J. L. Z., da Costa, C. A., & da Rosa Righi, R. (2019). Survey of conversational agents in health. In *Expert Systems with Applications* (Vol. 129, pp. 56–67). Elsevier Ltd. https://doi.org/10.1016/j.eswa.2019.03.054

O'brien, J. D. (2017). *Chatbots for Diabetes Self-Management: Diabetes coaching at scale*.

PitchBook. (n.d.). *PitchBook [home page on the Internet]*. Retrieved November 29, 2020, from https://pitchbook.com/

Ramchandani, N. (2019). Virtual Coaching to Enhance Diabetes Care. *Diabetes Technology and Therapeutics*, *21*(S2), S2-48-S2-51. https://doi.org/10.1089/dia.2019.0016

Retterath, A., & Braun, R. (2020). *Benchmarking Venture Capital Databases*. https://ssrn.com/abstract=3706108

Rui, P., Hing, E., & Okeyode, T. (2014). *National Ambulatory Medical Care Survey: 2014 State and National Summary Tables*. https://www.cdc.gov/nchs/ahcd/ahcd_products.htm

Schachner, T., Keller, R., & V Wangenheim, F. (2020). Artificial Intelligence-Based Conversational Agents for Chronic Conditions: Systematic Literature Review. *Journal of Medical Internet Research*, *22*(9), e20701. https://doi.org/10.2196/20701

Sosale, A. R., Shaik, M., Shah, A., Chawla, R., Makkar, B. M., Kesavadev, J., Joshi, S., Deshpande, N., Agarwal, S., Mahseshwari, A., Madhu, S., & Saboo, B. D. (2018). Real-World Effectiveness of a Digital Therapeutic in Improving Glycaemic Control in South Asians Living with Type 2 Diabetes. *Diabetes*, *67*(Supplement 1), 866-P. https://doi.org/10.2337/db18-866-p

Stein, N., Delury, K., & Paruthi, J. (2020). *One-Year Clinical Outcomes of an Artificial Intelligence-Based Digital Diabetes Prevention Program*.

Stein, N., Ku, R., & Mao, T. (2019). *Clinical outcomes from older adults in a digital diabetes pre-vention program*. https://doi.org/10.2337/dci18-0007

WHO. (2016). *WHO Global Report. Global Report on Diabetes*.

World Health Organization. (2018). *Classification of Digital Health Interventions v 1.0: a shared language to describe the uses of digital technology for health.* http://apps.who.int/iris/bitstream/handle/10665/260480/WHO-RHR-18.06-eng.pdf

Wu, X., Guo, X., & Zhang, Z. (2019). The efficacy of mobile phone apps for lifestyle modification in diabetes: Systematic review and meta-analysis. In *JMIR mHealth and uHealth* (Vol. 7, Issue 1). JMIR Publications. https://doi.org/10.2196/12297