Can Technology Alone Tackle the Issue of Medicine Adherence?

Though therapeutic treatments are generally trialled, approved and introduced based on the assumption of correct usage, actual patient adherence has been shown across a range of situations to be less than 50%, resulting in undertreated conditions, increased emergency admissions, and reduced public health outcomes. The issue applies not just to taking medication but also to correct and timely use of medical devices.

Technological developments aimed at addressing aspects of the problem range from standalone smartphone apps to intelligent medical devices and fully integrated telehealth systems.

But can this problem be solved by technology?

The Scale of the Problem
There is no doubt that medicine adherence is a significant problem. Various studies have shown that in developed countries the adherence to long-term therapy for chronic illnesses is less than 50%, and worse in developing countries. It is estimated that the cost of non-adherence in the USA is between $100 and $250 billion[1].

Non-adherence to prescribed therapy will in most situations result in a worse outcome, and often leads to the need for more expensive interventions. One study[2] estimated that non-adherence accounts for 10% to 25% of hospital and nursing home admissions in the USA.

Furthermore, the percentage of the burden on healthcare systems represented by chronic diseases is set to rise, making the cost of associated non-adherence more significant. Yet rates of adherence have not changed noticeably in the last three decades, despite World Health Organisation (WHO) and Institute of Medicine (IOM) improvement goals and an increased focus on implementing solutions.

Making the Business Case
There are clearly benefits to the overall healthcare system to addressing non-adherence.

For the vendor of a specific device or therapeutic agent, better patient compliance should lead to better outcomes, which (*if demonstrable in a formal trial*) should confer a competitive advantage.

For technology that purports to work across a number of different therapeutic areas, the savings in reduced interventions and improved outcomes must justify the overall investment, but are hard to prove *in the general case* by trials.

For a successful business case, the savings must accrue to the same budget holders who invest in the technology, not to another part of the organisation (which is not always the case). In some healthcare systems where the financial incentives are skewed towards billable treatment, improved adherence may even run counter to commercial interests.

Defining the Problem
In the past, adherence has been defined in many ways, such as "the extent to which a patient follows medical instructions", but that style of wording has been criticised because "instructions" implies a completely passive patient and such an attitude to treatment may form part of the problem. Though the question of non-adherence is generally framed as "Why doesn't the patient follow prescribed treatment?" it is also more broadly applicable in public health situations, such as, "Why do x% of parents not vaccinate their children against various diseases?" or, "Why do y% of adults fail to take sufficient exercise?" There are multiple causes for non-adherence, and therefore no single solution. As a result, there are a number of technological innovations which have been developed to address the various different aspects of the problem, which are all present to a greater or lesser extent in different patient groups.

The Centers for Disease Control and Prevention (CDC) in the USA lists five areas in which contributory factors to non-adherence can be found.

"Social and Economic" factors including, among others:
• Health literacy
• Cost or lack of insurance coverage

"Healthcare System" such as:
• Provider / patient relationship
• Patient education programmes
• Continuity of care

"Condition-related" such as:
• Lack of symptoms
• Depression caused by condition

"Therapy-related" such as:
• Complexity of treatment
• No immediate benefit of (or immediate deterioration after discontinuing) treatment
• Actual or perceived unpleasantness in the treatment or its side-effects

"Patient-related" including:
• Physical factors, such as sensory, motor or cognitive impairments
• Motivation

No single solution will address all of these in all groups, but there are certainly some obvious areas to target. For example, an estimated 25 to 30% of prescriptions are never dispensed. The leading reason for this is cost, but patients not understanding the rationale behind their treatment is also a significant factor. Though solving the problem of unfilled prescriptions may not be easy, monitoring it should be. A nationwide integrated system could track undispensed prescriptions and enable intervention by Healthcare Providers (HCPs). Though technically feasible, however, this would not be cheap, and the benefits don't necessarily flow to those who incur the costs.

Where the treatment presents patients in the target group with a significant physical or cognitive difficulty, it can be expected to lessen adherence. A 2002 study of 325 older people (average age 78 years) reported that 39% *were unable to read the prescription labels*. It may be clear what to fix in this case (even if the solution is not necessarily easy).

However, the same study of older patients showed that 67% in all did not fully understand the information given to them, and as a result 45% were non-adherent. There is a bigger problem than just label legibility.

Technological developments which make self-administered therapy easier (less complex, less painful, more discreet) show benefits in areas where these are identified as major issues. But often just making the patient's regimen of treatment less confusing can make a significant difference. According to one study[3], 29% of adults aged 57 to 85 were taking five or more prescription drugs. Combining an individual's medications into day-labelled packs at dispensing time can help. And simply simply changing the appearance of a medication can result in a decrease in compliance[4]; when a pill looks different, patients often simply stop taking them as prescribed. There have even been proposals from regulators to mandate that generic drugs look like the branded originals to address this issue.

Young patients with certain conditions also show low compliance, but for different reasons to seniors. Teenagers are frequently reported by clinicians as "thinking they are immortal" when it comes to compliance with long-term drug regimens, and may require regular testing to confirm "correct drug function" (and hence compliance).

Achieving optimal compliance may be the result of many interventions, each addressing different parts of the overall problem.

The Role of the Healthcare Provider
The extent to which the HCP accurately communicates the particulars of the disease and the therapy has a significant effect on adherence, as evidenced by some of the factors which are shown to be associated with poor adherence (health literacy, quality of provider/patient relationship). Adherence is lower in diseases where the symptoms respond slowly to the treatment, implying that the patients don't have faith in the treatment. Anecdotal evidence from doctors indicates that many patients may stop treatment once they are feeling better, regardless of instructions to the contrary.

Guidelines have been developed for HCPs for improvement of compliance, which encourage better communication

about the therapy, modification of patient beliefs and behaviour, and continual monitoring of adherence. In the absence of automatic measurement systems this monitoring will involve patient reporting.

Self-reporting of adherence has been an area of significant study. In 2008 Donald Morisky proposed a simple eight-point questionnaire which could assess not only the level of non-compliance, but also the causes (such as forgetfulness). The key breakthrough in this work is the realisation of the importance of *objective* compliance measurement. All patient conversations are not equal.

One doctor described the sensitive nature of adherence conversations thus: If the clinician asks a leading question "Did you take all your tablets this month?" a significant proportion of patients will incorrectly answer yes. Then, having lied once, *they can never back down* and the relationship proceeds that way thereafter. But if the clinician opens the conversation with "How many doses would you estimate you missed this month?", the conversation can then address the reality openly. This illustrates to some extent the difference between treating the patient as a passive follower of instructions, and allowing them to take more ownership of their treatment. If, for example, dose-counting technology is there to *monitor* a patient who would otherwise misrepresent their compliance, it needs to be harder to circumvent than a dose-counter that is simply there to help a willing patient who struggles to comply. The relationship with the healthcare provider and the motivation of the patient can have as much impact as a technological solution.

The Role of Technology
Few doubt that if every patient had their personal physician by their side 24/7, compliance would be near 100%. The same principle applies for a personal dietician or a personal trainer. But for all but the super-rich, this is unaffordable. A technological solution may be imagined as either taking the place of such a personal assistant, to remind, motivate, inform, cajole, assist and record the patient's daily treatment, or else as empowering the patient to do it for themselves. Different patients will respond to different approaches.

In the simplest case, assistive technology uses a reminder system. A

smart pill bottle, a phone app, or an automated SMS or phone call may address the situation where the patient is either unsure or forgetful about the correct time and amount of treatment. Research shows that these interventions are highly effective at first, but the effectiveness declines with time. More sophisticated reminder systems may vary the message, but this approach only addresses a certain cause of non-adherence.

If the system includes a feedback mechanism, some degree of near real-time monitoring is possible. There has been much work in telehealth systems, which can remind and report on compliance with treatment but also, via sensors or self-reporting, monitor symptoms of conditions such as chronic obstructive pulmonary disease (COPD). With some medical conditions there are significant cost and health benefits if early warning of exacerbations that would otherwise lead to emergency admissions can be acted upon. A sophisticated telehealth system has the potential to continually remind, motivate and educate the patient about their illness, using messages that are tailored to the particular patient and to their particular reasons for non-adherence. The challenge, as with any medical personalisation, is to create and maintain a patient-specific service while retaining the promised benefits of economy of scale.

More sophisticated yet is a device which evaluates the quality of the treatment event. These range from the simple (an inhaler which whistles when the child achieves the correct inspiration flow) to the complex (one which measures, stores and wirelessly transmits the flow profile to the cloud, but also allows a patient to see it for themselves on a smartphone or tablet). The idea here is that your "personal physician" tells you how to use the device - a great improvement on an actual physician who, research shows, is 90% likely to not know themselves[6].

Linking Motivation and Behaviour
There is a large overlap between the relatively new field of "wearable" technology and the use of smart, connected medical devices. Their designers often share a common goal of being able to effect and monitor long-lasting behavioural change. A key application for modern wearable technology, exercise tracking, already

has a saleable value to both end users and public health bodies and although systems are available for relatively low cost, it remains to be seen as to whether they can sustain the desired behaviour.. If a foolproof system for making any given person exercise regularly could be found, the same principles would surely be at least partly applicable to therapeutic adherence.

B J Fogg, at the Persuasive Technology Lab at Stanford University, has proposed a behaviour model[7] in which desirable behaviour can occur as the result of suitable external triggers, provided that the products of motivation and ability are above a certain "activity threshold". So an unmotivated person can be triggered to do something easy (high ability) but only a highly motivated person can be triggered to do something difficult (low ability). Trigger events need to get the user's attention, be clearly associated with the target behaviour, and also be suitably timed so that they occur when ability and motivation combined put the user above the activity threshold.

Applying this model to a smart medical device, the designer would ask "When is the optimum time to trigger this user to use the device to maximise the chance of success?" and also, "If the user is not above the activity threshold, is this because of motivation or ability?"

Addressing ability does not *just* mean making the device physically easy to use for the target group. If it takes too long, costs the user money, can only be done in a particular place, or makes the user feel physically or socially uncomfortable, this contributes to the user having low ability.

Even something which requires a bit too much thought may put the user below the activity threshold, depending on their mental state at the time. Just because the patient demonstrated that they could use the device after being instructed in the clinic environment does not guarantee high ability at home at all times of the day. Patients also find things easier if they can make the activity part of a routine - irregular treatment intervals reduce ability.

Fogg identifies three fundamental categories of motivation. Pleasure/pain, hope/fear and social acceptance/rejection (and asserts that the positive side of each is the more ethical to target).

Social acceptance has become more relevant with the rise of social media. It's easier to stick to an exercise programme if there are other people doing it with you, and social apps aim to create that same effect even if the other people are remote (or strangers).

Finally, the nature of the trigger itself is important. With systems based on modern smartphones or tablets, the trigger can involve text and other media tailored to the occasion. When a subject has both motivation and ability, the trigger need only be a reminder. If they lack motivation, the trigger should aim to remind them *why* they should want to take the action. (In November 2014, Medisafe announced that they were adding more informative content to their adherence smartphone app that would aim to further educate the patient about their condition, which they had clearly recognised as a key factor.) But if the patient at the time of the trigger lacks ability, the trigger should offer some assistance with actually taking the action. The wrong kind of trigger will have little or no effect.

Habit
The aim with long-term conditions is ideally to build *habits* rather than rely on finding ways to motivate the user forever. There has been much discussion (both academic research and in the popular literature) related to habit formation.

Habit formation involves phases. In the first phase the new behaviour is hard and takes commitment to complete. In the second phase it has become relatively effortless but is still not embedded behaviour. If the subject were to not be reminded, they might stop doing the action and maybe not notice. But in the third phase the behaviour becomes normal, and to not perform the action might feel unusual. A daily habit is said to take approximately a month to build. One device company found from user feedback that contrary to expectations some patients preferred a daily self-injection to a once-weekly injection. One theory was that an unpleasant injection once per week requires repeated application of motivation and willpower, but a daily injection is so regular it becomes a habit and as such is easier to face. (Of course, the daily injection may have been smaller and less painful.)

The upshot of this is that, for long-term treatment of a chronic condition, it makes sense to invest more in supporting compliance in the early stages (focusing on both motivation and ability) and then, once the habit is established, revert to less complex "reminder" systems. This approach is already used with "trainer" inhalers which are used for an initial period to establish behaviour.

Technology Implementation
There are several current trends which have no doubt accelerated the development of medical adherence devices. The increasing prevalence of smartphones, the internet of things, "wearables" and the ubiquitous internet all offer a landscape that supports more rapid development of working prototypes. Technologies such as Bluetooth Low Energy that make it viable for devices to monitor and report key parameters for months or years on a single battery are now widely supported by off-the-shelf control hardware. Whereas five years ago a developer might need to build an entire system end to end, there are now hardware development kits and reference designs for prototyping devices, and "out of the box" ready-made hubs and cloud systems that can be used to carry the data from the device all the way to the back-end system. Furthermore, technology adoption is changing rapidly, with senior patients increasingly likely to be tablet- or smartphone-literate.

Of course, while working prototypes can now be created more rapidly, the regulatory requirements for development of actual medical devices remain onerous. Any device or system which transmits identifiable patient data must also comply with various data security requirements (including high-strength encryption). Furthermore, recent FDA guidelines indicate that devices and systems will in future be expected to determine whether their data systems have been compromised. Addressing these requirements can be expensive, hence the attraction of using existing infrastructures where approvals are already in place.

So Can Technological Solutions Work?
Specific solutions that accurately target a known cause of non-compliance can be expected to provide improvements. Where improved compliance measurably reduces incidence of hospital admissions or irrevocable deteriorations, the

commercial case may be straightforward to make.

Where compliance improvement results in marginal improvements in long-term therapeutic outcomes justification will depend on the cost model.

When it comes to larger integrated telehealth systems, the intent is generally to address more than just adherence. Numerous studies have shown effectiveness for measures such as service utilisation, user experience and social care outcomes.

However, the commercial assessments are less equivocal. An effective telehealth system requires significant investment. A March 2013 paper submitted to the *British Medical Journal* by researchers from the London School of Economics assessed the UK Government's "Whole System Demonstrator" programme. It determined that the addition of telehealth cost £92,000 per quality adjusted life year (QUALY). The UK's National Institute for Health and Clinical Excellence (NICE) has a threshold to approve a drug or technology of £30,000 per QUALY. Put another way, even if telehealth is technically effective, it is three times too

expensive to meet the requirements for use in the UK. The metrics in other countries (and indeed other payer systems) may vary, and costs may fall in time.

Conclusion

Innovative technology can be used in many ways to improve adherence, for example:

- to track prescription drug follow-through (i.e. filling of prescriptions)
- to assist with or simplify complex treatments to make correct use as easy as possible
- to remind users which treatment they should take and when
- to educate and motivate users about their treatment
- to provide patients and healthcare providers with use feedback and in some cases, early warning of serious events.

However:

- it is necessary to ensure the technology addresses the actual causes of non-compliance, which will vary between therapies, between patients and even at different times of day with the same patient
- because non-compliance is largely a behavioural rather than a technical issue, care should be taken to objectively report the non-compliance on which technological developments are to be based
- because subtle factors can have significant effects on adherence, any evidence-gathering trials must be truly representative and meticulously observed.

And finally

The interaction between HCP and patient

is key, as it establishes understanding of (and belief in) the treatment. It's unrealistic to expect a technological solution to completely replace a professional interaction, however tempting the financial case.

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