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The Impossible, the Unlikely, and the Probable Nudges: A Classification for the Design of Your Next Nudge

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Abstract: Nudging provides a way to gently influence people to change behavior towards a desired goal, e.g., by moving towards a healthier or more environmentally friendly lifestyle. Personalized and context-aware digital nudging (named smart nudging) can be a powerful tool for efficient nudging by tailoring nudges to the current situation of each individual user. However, designing smart nudges is challenging, as different users may need different supports to improve their behavior. Determining the next nudge for a specific user must be done based on the user's current situation, abilities, and potential for improvement. In this paper, we focus on the challenge of designing the next nudge by presenting a novel classification of nudges that distinguishes between (i) nudges that are *impossible* for the user to follow, (ii) nudges that are *unlikely* to be followed, and (iii) *probable* nudges that the user can follow. The classification is tailored to individual users based on user profiles, current situations, and knowledge of previous behaviors. This paper describes steps in the nudge design process and a novel set of principles for designing smart nudges.

Keywords: smart nudging; digital nudging; behavioral change; personalization and context-awareness; nudge classification; adaptive nudging; principles of smart nudge design; determining the next nudge

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1. Introduction

For many people, a behavioral change in a certain direction is desirable. This may, for example, be a change towards a healthier lifestyle (such as being more physically active, losing weight, or quitting smoking) or adopting more environmentally friendly habits. However, changing one's behavior may be challenging to achieve without the help. In this paper, we focus on personalized and context-aware digital nudging as an aid to support behavioral change.

A *nudge* represents a gentle push towards a desirable goal, and is designed to influence people to make beneficial decisions for society and/or individuals. The concept originates from economics and political theory for influencing decisions and behavior using suggestion, positive reinforcement, and other non-coercive means to achieve socially desirable outcomes [1].

Nudging is defined as ". . . any aspect of the choice architecture that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives". *Choice architecture* refers to "the environment in which individuals make choices" [1]. The authors of [1] state that "To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates. Putting fruit at eye level counts as a nudge. Banning junk food does not".

Digital nudging, as provided through an application on, e.g., a mobile device, can be a powerful tool for many people in their struggle for behavioral change. In [2], digital nudging is described as a "subtle form of using design, information and interaction elements to guide user behavior in digital environments, without restricting the individual's freedom of choice".

Digital nudging can be inexpensive, and through the widespread use of mobile devices has the ability to reach a huge number of users. It enables personalization of nudges, where a user's current behavior and situation is used as a basis for tailoring the next nudge to the individual. In [3], we define personalized and context-aware nudging, named *smart nudging*, as "digital nudging, where the guidance of user behavior is tailored to be relevant to the current situation of each individual user".

A smart nudging system monitors user activities and interests and suggests, based on the nudging goal, activities that go beyond the user's typical behavior. A nudge provides the user with a suggested activity, together with a gentle influence, to make the user follow the suggestion.

A challenge for a smart nudging system is to determine which nudge to design for a specific user in each situation. At the time of nudge design, several activities and different ways of influencing may be useful, and it may be impossible, and even useless, to determine that one specific nudge is "the right one". Determining the *next nudge* is often about filtering out the useless nudges and selecting one of the remaining valuable nudges.

The effectiveness of nudging has been reported by a number of researchers. The work of [4] reviews research on the use of nudging to promote physical activity and reduce sedentary behavior in the workplace. There, 26 studies of intervention effects were included, where a significant positive effect was found in fourteen studies, a positive trend was found in six studies, a mixed intervention effect was found in five studies, while no effect was found in one study. A similar trend is seen in the review study of [5], which found that most papers, including user studies (eight out of eleven), reported that at least one nudging mechanism impacted user behavior. The remaining three papers did not report significant effects of nudging.

Personalization is considered promising for tailoring digital nudging to the users' specific needs, with the intent of improving nudge efficiency. However, personalized nudging is currently understudied [5–7]. In our approach, we target this deficiency by focusing on personalization, together with context awareness, in the design of nudges.

Our research has been organized into a number of sub-projects where solutions for different components of a smart nudging system have been designed and implemented. Based on our work conducted over several years, we have gained insight into what is required for the design of smart nudges and revealed the need for tools to guide the design process. This knowledge has led to the contributions of this paper.

In this paper, we present a novel *classification of nudges* and *principles for smart nudge design* that can be used as tools when designing the next nudge for a user. We describe how the next nudge can be designed through a set of design steps.

2. Related Work

2.1. Nudge Classification

Nudges are commonly classified according to how they affect the person receiving the nudge. The work of [5,6] classifies nudging mechanisms based on psychological effects for behavioral change and how users are influenced. In [5], 87 nudging mechanisms are identified and organized into a taxonomy of four main categories: decision information, decision structure, decision assistance, and decision affection. A similar approach is followed in [6], where 23 nudging mechanisms are classified into six overall categories. In [8], nudge classification is based on the influence used in the nudge, resulting in ten important nudges.

A different approach to nudge classification is seen in [9], where two broad categories, labeled pro-self and pro-social nudges, are presented. Pro-self nudges are aimed at benefiting the nudged person, while pro-social nudges are primarily aimed at benefiting society.

In this paper, we suggest a different way of classifying nudges, focusing on the user's ability to follow the nudge. Our classification therefore complements other classification schemes and provides a new perspective that is useful when selecting the next nudge for a user.

2.2. Principles of Nudge Design

Design principles for persuasive technologies are described in, e.g., [10,11], and many of them are relevant for smart nudging systems. In [11], the authors include principles for dialog support, where feedback to the user is focused, system credibility support, which includes the trustworthiness and perceived expertise of the system, and social support, which describes how to design a system that motivates users through social influence. This includes the principle of personalization, which should offer personalized content and services to users.

The principles described in [10] target other design strategies for persuasive technologies. These include using data abstractions to illustrate user behavior, present and collect data in an unobtrusive manner, and use positive reinforcement to encourage change.

Specifically focusing on nudge design, [12] describes a design cycle with four steps, which include (i) defining the goal, (ii) understanding the users, (iii) designing the nudge, and (iv) testing the nudge. The steps are followed by questions that need answering during the design process, but they are not detailed into more specific nudge design principles. In [2], the authors describe a similar type of model, the DINU model, where behavior change elements from both nudging and persuasion are combined. Their work separates digital nudging into three phases, including (i) analyzing requirements for nudging, (ii) designing a nudge using the correct motivational elements and considerations (e.g., ability and context), and (iii) evaluating the designed nudge after implementation.

There are ethical guidelines for the construction of digital nudges. In [13], the authors present ethical guidelines as a check-list that includes three conditions for nudging: transparency, ease of resistibility, and non-controllability.

In this paper, we present a set of principles for smart nudge design that focuses on personalization, context-awareness, and adaptability in the design process. This represents a new angle to nudge design that complements previous guidelines and principles.

3. Smart Nudging

Designing a smart nudge requires the identification of an activity or an action that supports the desired behavioral change as well as a way of influencing the receiver of the nudge. In this section, we describe nudge components and an architecture for a smart nudging system, then argue for adaptive nudging.

3.1. Nudge Components

A nudge is an intervention that gently steers an individual towards an activity that supports a desired nudging goal. For example, nudging towards "taking a walk" supports the goal of making people more physically active.

A smart nudge can be described as *Smart Nudge* $= \{A, I, C, T, P\}$, where A represents the *activity* selected for the nudge, I is an *influence* (or motivation) provided by the nudge, C represents the *contents* (i.e., practical information) that is needed or useful when following the nudge, T is the *time frame* when the nudge is to be effective, and P represents *presentation* properties (i.e., how the nudge is presented to the user).

The actual components of a smart nudge are based on our experience developing systems creating and presenting smart nudges. The components $\{A, I, C, T, P\}$ include the information and data regarding a smart nudge that we currently find necessary to create and present a successful nudge.

The $\{A, I, C, T, P\}$ components of a nudge are described and exemplified in Table 1, using "physical activity" as the nudging goal. Considering this goal, relevant activities include walking, skiing, cycling, squash, and swimming. The table provides examples of practical information related to these activities (e.g., how to reach the activity, cost of participating, and the condition of the trail) along with ways of influencing the user to select the suggested activity. The influence is related to psychological effects for behavioral change, and is described in more detail in [14], where a number of nudge-type influences are linked to psychological effects.

Table 1. Examples of nudge components supporting the nudging goal of "physical activity".

Component	Description	Examples
Activity	Activity selected for the nudge	Walking, hiking, skiing, cycling, dancing, squash, swimming
Influence	Using information and design of nudge to affect the user towards selecting the activity.	Information about the health benefits of the activity. Using photos of attractive views along the hiking trail. Presenting points of interest along the suggested path. Remind the user of a previously made activity plan. Social influence, by informing the user of what others are doing.
Contents	Practical information	Location of activity. Path to follow, length, difficulty, conditions of trail (for e.g., hiking or skiing). Cost of participating, opening hours (for e.g., squash or swimming). How to reach the activity, directions, parking, bus routes. Current weather and weather forecast.
Time frame	The targeted point in time for the activity.	Nudge to join a friend that is leaving for a walk now. Suggesting a walk in the afternoon or a hike in the weekend.
Presentation	How to present the nudge on a mobile device.	Can be described through rules and/or guidelines.

The time frame component represents the targeted point in time when the nudge should be carried out, assuming that it is accepted by the user. A nudge either requires the user to engage in the activity immediately (or within a short time frame), or can make the user commit to an activity in the future.

Presentation represents rules and guidelines for how nudge components are combined and displayed to the user. Requirements and limitations to the presentation of a nudge come from both the device where the nudge is presented (typically a mobile phone), and the influence component that can impact the design, display, and interaction between the user and nudging system.

3.2. System Architecture

The architecture for a smart nudging system is presented in Figure 1. Central to the architecture is the *Nudge Design* component that creates smart nudges relevant to the nudging goal based on personal information and context awareness. Personal information is obtained from the user profile, while user context includes, for example, location and available time for following a nudge.

The *User profile learner* is responsible for creating a user profile containing useful information when designing smart nudges. This implies collecting personal data, such as user interests, capabilities, and activity history. To adapt nudging to the user's current need for improvement, the system monitors user activity to detect the current level of behavior and changes in behavior over time. It monitors reactions to previous nudges (i.e., accept or reject) to detect characteristics of nudges that were positively received by the user. This knowledge can be used as input when designing new nudges.

A nudging system relies on data collected from various sources that provide user context information and practical information as well as information used to influence the user. For example, GPS positioning provides the user's location, available time can be detected through the user's calendar, information about walking/hiking trails and weather conditions can be obtained through online sources, IoT devices can inform about air pollution and conditions on the ski trail, and users of the system can contribute with comments and photos taken while being active.

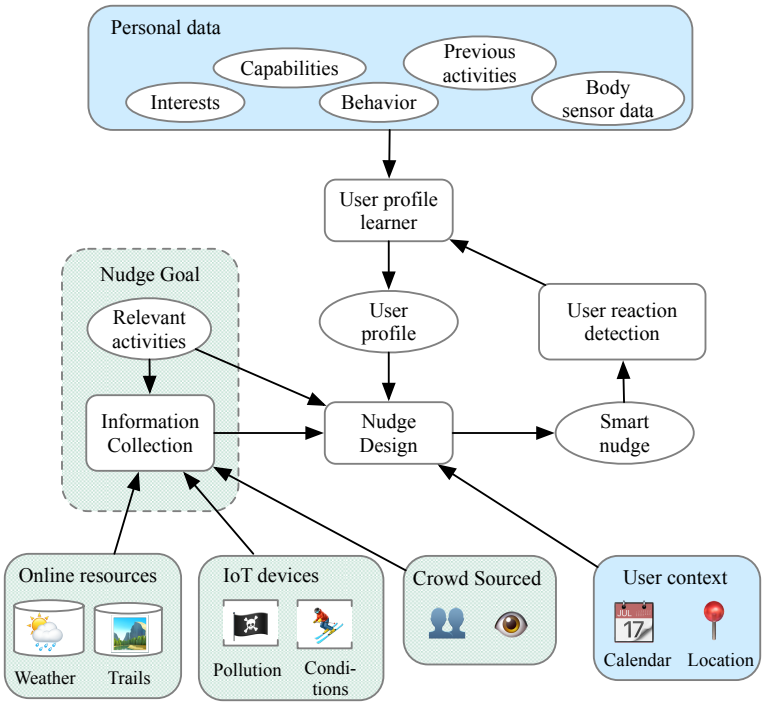

Figure 1. Smart nudging system architecture.

Description of a variety of trails for walking, hiking, cycling and/or skiing is available on different online sites, for example AllTrails.com. For each trail, we find information such as the type of activity (e.g., walking, hiking, skiing), length, estimated duration, elevation gain, difficulty, location (through position and map), how to get there, parking, and photos from the trail. With respect to nudging, we consider each trail a separate activity, and trail information can either be used for determining the relevancy of the activity (a specific trail can, e.g., be too challenging for the user), used as practical information in a nudge (e.g., location and parking), and used for influencing the user (through, e.g., nice photos from the trail).

3.3. Adaptive Nudging

A smart nudge is designed to fit the needs of a specific user. This means that the situation of the user (including activity level, interests, capabilities, available time, location, and environment) determines which nudges are currently relevant for the user. As the situation of a user changes, nudging is adapted. For example, when the user's activity level increases, nudging can be adapted by (i) providing fewer nudges, as the user is now increasingly active and/or (ii) providing nudges for more challenging activities, which the user is now capable of doing.

The system should further adapt to user habits and reactions to previous nudges by, e.g., learning over time the best time frame for nudging and which activities and motivational effects seem to be most effective. The need for practical information may vary over time, and the nudging system must adapt accordingly. The system should, for example, avoid overwhelming the user with already-known information.

A nudging system has an overall goal representing the basis for all nudges designed in the system. In addition, users may have *personal goals* consistent with the overall goal. In a system where "increased physical activity" is an overall goal, a specific user may commit to a personal goal of "running a marathon". A personal goal can be seen as a change in the user's situation and cause the system to adapt nudges, making suggested activities support the personal goal.

Personalization and changes in the user's situation make adaptive nudging necessary. The inability to adapt can cause nudges to be irrelevant and ineffective. If nudges are not relevant to the user's current situation, the user may find the nudges annoying and stop using the system.

4. Classifying Nudges and Nudge Components

There is no one correct answer to the question of which nudge should be the next. The situation of a person can open them up to a number of different nudges that may all be useful for supporting both the personal and the overall nudging goal. Therefore, instead of selecting a correct nudge, the focus should first be to rule out useless nudges.

To determine relevant nudges for a user, we classify nudges as *impossible*, *unlikely* (to be accepted by the user), and *probable* nudges (that have the potential to be accepted by the user). This classification is carried out with respect to the activity suggested in the nudge. Section 4.1 describes our nudge classification, while Section 4.2 describes the content, influence, and time components of a nudge along with how these components can be characterized.

4.1. Nudge Classification

The activity selected for a nudge is the main aspect that determines the usefulness of a nudge. The other components of a nudge merely support and promote the selected activity. In the following sections, we present a novel nudge classification, which is summarized and exemplified in Table 2. The classification is used to filter and sort possible activities. The selected classification classes are created to simplify this process. We use this to eliminate the ones that are not relevant and to focus on the ones that are most relevant.

Table 2. Classification of nudges

Class	Reason	Last	Based on	Examples
Impossible	Physical disability	P/T	User profile	Because of a permanent disability or temporary injury, the user can only walk short distances.
	Lack of equipment	P*	User profile	User does not have (access to) a bike or skis.
	Lack of skills	P*	User profile	User cannot swim or has never skied.
	Wrong season	T	Time of year, location	Unable to ski during summer.
	Lack of time	T	Calendar, time of day	Short time to next meeting, too late in the day (it is dark soon and the activity requires daylight), the activity is closed or closes soon.
	Logistic reason	T	Previous activities, location	If the user has walked to work, she should not be nudged to take the bicycle when going home. The activity is too far away.
	Situation/ environment	T	Location, environment	Road congestion on the way to the activity. Harmful air pollution in the area hinders outdoor activities.
Unlikely	Activity is too challenging	T	User behavior	Gap between the activity and the user's current activity level.
	Wrong timing	T	User behavior	User has recently been active.
	Activity is outside user interests	T	User behavior; user profile	User has rejected this activity a number of times.
Probable	Activities that are not classified as impossible or unlikely.			

P: permanent, P*: conditionally permanent, T: temporary.

4.1.1. The Impossible

An impossible nudge includes an activity that is not possible for the user to do. There are several reasons for inability to perform an activity, including physical disabilities, lack of equipment and/or skills, lack of time, logistical reasons, and environmental conditions.

Certain activities are permanently impossible. Others are only temporarily impossible. A physical disability can either be permanent or temporary (e.g., a broken leg), making certain activities permanently or temporarily impossible. An activity can be permanently impossible under certain conditions. This includes activities where the user lacks equipment or skills. The activity remains impossible as long as this situation continues, although if the right equipment or skills are obtained, the activity becomes possible.

Information in the user profile is important for identifying impossible activities. By registering physical disabilities, available equipment, and lack of skills, the user avoids being nudged towards activities he or she cannot do. We find that the user's calendar, location, environment, and time (such as the time of day or season) are helpful in identifying currently impossible activities.

From the user's calendar, the system may learn when the user is busy and when she has available time slots to be active. Time of day or season may temporarily exclude activities. For example, if the activity is outdoors, it may be getting too dark to safely engage in it, or it may be the wrong season. The distance to an activity can make it impossible within the user's current time frame.

The environment can affect the possibility of engaging in an activity. A high level of pollution, an ongoing storm, or a dangerously slippery trail can temporarily cause an activity to be considered impossible.

4.1.2. The Unlikely

Based on the activity history of a user, it is possible to identify activities that are unlikely to be accepted by the user. For example, if until now the user has taken only short, easy walks, it is unlikely for a nudge towards a challenging mountain trip to be accepted. It may even be harmful to nudge for an activity the user is not fit for.

For the most part, determining unlikely nudges is based on knowledge of the user's behavior (or level of activity) and reactions to previous nudges. To determine whether an activity is too challenging, we use a distance measure D that calculates the distance between the current activity level A and a specific activity X, i.e., $D(A, X)$. The value of $D(A, X)$ is based on a set of attributes, for example, the length and difficulty of the activity, and we use a threshold value to identify unlikely nudges. Thus, if $D(A, X) > threshold$, the distance between A and X is too large and X is considered an unlikely activity.

Another relevant measure of distance is $D(C, X)$, where C is the most challenging activity the person has previously done. A person can normally engage in less challenging activities (e.g., short walks in easy terrain). Then, $D(A, X)$ may be large. However, if the person occasionally performs more challenging activities, the distance $D(C, X)$ may be within the threshold. This makes nudging for X more likely to be accepted.

The timing of a nudge is crucial for the possibility of it being accepted. If the user has recently been active, a nudge for more activity may be untimely. This can be detected by monitoring user activity. The user may have regular habits that are incompatible with training (such as a regular dinner time, an afternoon nap, or time for putting children to bed). By analyzing previously rejected nudges, the system may detect such time periods where acceptance of a nudge seems unlikely. Alternatively, such periods can be explicitly registered in the user's calendar or used as input to the nudging system.

Nudging for an activity entirely outside the user's interests may be difficult and represent an unlikely nudge. Which activities to avoid, can, in this case, be detected by analyzing previously rejected nudges or through explicit registration of interests in the user profile.

4.1.3. The Probable

A probable nudge is a nudge that the user is capable of performing. Considering the user's situation, it is a nudge that the user is likely to accept. This means that a probable nudge includes an activity that is not classified as impossible or unlikely. As many activities

can be temporarily impossible or unlikely, the user's situation and environment determine whether an activity is classified as probable.

At a specific point in time, a set of activities may be classified as probable and all be considered valid choices for a nudge. Thus, without more knowledge about the user, each probable activity may be equally useful to nudge for.

However, further classification can be based on user reactions to previous nudges. For example, an activity may be more likely to be accepted if the nudging history shows that the user has often accepted this activity in the past or if the user has set a personal goal and the activity is relevant for reaching the goal. This implies that the system may rank probable activities according to relevant measures. Identifying the most probable nudges may improve the acceptance rate for nudging.

4.2. Characteristics of Other Nudge Components

In addition to the activity component, a nudge includes an element of influence, a time frame, and practical information that helps the user when performing the activity. In this section, we describe and classify these components with the intent of choosing the information and motivational effects most beneficial for selecting the next nudge.

4.2.1. Influence

A nudge includes a motivational component that should influence the user to follow the nudge. Different influence types for nudging, all related to the psychological effects of behavioral change [8,14,15], are described and exemplified in Table 3.

Table 3. Types of influence.

Influence	Description	Example
Affect	Evoking positive emotions by using, e.g., emotional images.	Use pictures of an attractive view to trigger hiking.
Anchor	Use initial information to guide decisions.	"You ran 10 km last week. How long will you run today?" To make the user determine today's distance based on the previous.
Commitment	Use pre-commitment strategies to change behavior.	Set up a plan for exercising and use this as a personal goal.
Informing	Informing what consequences actions can have.	Information on health benefits from being physically active.
Incentives	Using incentives to change behavior.	Discount when starting a gym membership or buying a season ski lift card.
Loss Aversion	Evoke the feeling that something can be lost if not acted upon.	Inform that the user is about to lose his current training streak, or suggest an activity today since the weather turns worse tomorrow.
Social	Informing what others are choosing.	Others (friends or respected public figures) choose to do *<selected activity>*.
Priming	Give cues to trigger association.	Displaying objects, e.g., images, that are associated with wanted behavior. Illustrating e.g., strength or achievement.
Salience	Making consequences or previous commitments more noticeable.	Use a nudge to help follow up a previously made plan.
Simplification	Remove unnecessary options or complicating tasks.	Provide easy access to all information needed to engage in an activity.

Initially, every type of influence may be equally possible or valuable. As the history of nudging grows for a particular user, the knowledge of motivational effects that have previously been specifically valuable can be expected to grow. After a period, the system may classify effects as *likely* or *unlikely* to motivate the specific user, and may avoid using unlikely effects in future nudges.

However, to be able to identify the not-as-useful motivational effects, the user must be exposed to all available effects over time. Without feedback from the user, it may be challenging to determine why a nudge was not accepted. A negative response to a nudge can be because the activity was not tempting, the timing was wrong, or the weather was too bad, and the motivational effect was not strong enough to overcome these obstacles. This need not imply that the next nudge cannot be successful using the same motivational effect.

A large amount of historical nudging information must be available to identify patterns around which motivational effects are useful or not. We believe that until such an amount of historic nudging data is collected, the motivation component can be freely selected.

To obtain reliable information on why a nudge was not followed, the nudging system can support explicit feedback from the user. This implies that users can rate the nudge based on its usefulness and indicate the reason why it was not followed, e.g., the activity or timing was wrong or the activity did not seem tempting. However, providing such feedback requires effort from the user, and can only be optional.

To identify the most effective motivational effects, it is possible to analyze the acceptance of nudges in a group of similar users. This can identify patterns concerning other aspects of the nudge, such as timing, selection of activity, and use of practical information.

4.2.2. Contents

The practical information in a nudge is tightly coupled to the selected activity. It should include information that helps the user and makes it easy to choose and perform the activity. Information is thus provided to increase the likelihood that the nudge is accepted and the activity performed.

We distinguish between essential and non-essential information for a nudge. *Essential* information is considered necessary or highly useful for the user to perform the activity. *Non-essential* information is not necessarily needed, although it is relevant to the activity and may be useful for the user. For example, the activity's address may be essential, while a map pinpointing the location may be considered non-essential, though useful.

Essential and non-essential information is presented differently to the user. While essential information is automatically provided the user, non-essential information can be available if the user explicitly requests it (through, e.g., an extra click on the mobile).

The experience and knowledge of a user may determine how essential or non-essential information is. When suggesting an activity for the first time much of the information concerning the activity is unknown to the user, and is thus classified as essential. As an activity continues to be used and the user knows the activity, information previously classified as essential can become non-essential. This includes relatively static information such as the location of the activity, parking lots, costs of attending, or the length and difficulty of a hiking trip.

Dynamic information that describes the current situation, such as the condition of the hiking trail, harmful air pollution, weather information, or road congestion on the way to the activity, may always be considered essential.

4.2.3. Time Frame

A nudge is provided with the intent of making the user engage in an activity, where the activity can take place within either a short or a long-time frame. As seen in Table 4, we distinguish between long-term and short-term nudges, where a *short-term nudge* targets an immediate (or almost immediate) action from the user while a *long-term nudge* suggests an activity that is to take place at a later time.

Table 4. Time frame for nudges.

Time Frame	Types	Description	Example of Nudge
Short-term	Immediate	Suggests an immediate action	Nudge for a walk now or catch the bus leaving in 10 min.
	Near-time	Suggests an activity within a time interval	Nudge for a walk in the afternoon or a hike in the weekend.
Long-term		Suggests an activity at a later point in time	Suggest an upcoming competition or to join a hiking holiday.

Certain nudges need an immediate reaction from the user, for example, if a friend invites you to go for a walk now. Planning ahead is possible through *near-time nudges*, where the user can commit to activities close in time. The system can use such a commit to allocate time in the user's calendar and issue an *immediate nudge* at the time when the activity is to start.

A long-term nudge can suggest an activity that is considered challenging and is therefore classified as unlikely. However, for a long-term nudge an unlikely activity may be used, and whether it is accepted or not depends on the courage and ability of the user to accept a challenge. An accepted long-term nudge can serve as a *personal goal* for the user, and the nudging system can design short-term nudges that support this goal.

5. Determining the Next Nudge

Designing the next nudge involves several steps, as illustrated in Figure 2. The next nudge is typically triggered by a situation or event, after which the nudging system selects an activity and a time for performing it. A way of influencing the user is selected and practical information concerning the activity collected. Lastly, the information is combined and presented to the user as a nudge. The design steps are affected by the user profile, the context and situation of the user, and overall principles for smart nudge design.

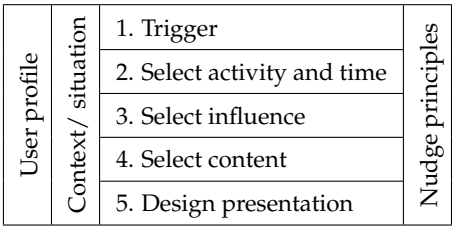

Figure 2. Steps in a nudge design process.

In the following, we first describe each step in the design process, then provide a few general principles for smart nudge design in Section 6.

5.1. Triggering a Smart Nudge

A smart nudge is always personalized based on the user profile and information about the user's situation and context. Thus, nudging is adaptive with respect to what to nudge for and when to nudge. The design of a nudge can be triggered by the user situation, environmental conditions, and/or an activity event that is relevant to the user. Below, we describe several situations that may trigger a nudge.

- *Time interval from last activity.* To help the user maintain continuity of activities, the system can nudge the user when the idle time (i.e., the time between activities) has reached a threshold. For light activities, the time interval between activities should be shorter compared to the interval between hard or challenging activities.

- *Committed schedule.* If the user has agreed to perform a certain activity (such as going to the gym each Tuesday), a nudge can be provided before the scheduled time.
- *Activity pattern.* Over time, the system may detect a pattern in the user's activity. If the user tends to be active in certain situations (e.g., in the afternoon if the weather is nice), the system can trigger a nudge when such situations occur.
- *Social trigger.* Activities performed by friends can trigger a nudge. For example, if a friend is going for a walk, the user can be nudged to join.
- *User situation or environment.* Conditions of the environment (e.g., nice weather or good conditions on the ski hill) may trigger a nudge. The same may be situations that positively affect the user's ability to be active (e.g., an upcoming holiday).
- *Event.* A mountain race or running contest may trigger a long-term nudge. An event or discount at the gym may be a trigger as well.

To promote user improvement, rules for triggering nudges cannot completely follow user preferences as identified through activity patterns or committed schedules; they must include an *improvement factor* to make the user stretch towards better behavior. This implies that situations or conditions for triggering a nudge may evolve over time.

5.2. Select the Activity and Time

After nudging is triggered, the system determines the time frame and selects an activity for the nudge. As described in Section 4.1, the time frame and activity are closely connected, as the user's available time determines which activities are possible to suggest in a nudge.

The system can thus either start by finding an available time slot and subsequently selecting a possible activity, or select an activity and subsequently find an available time. However, in many cases the reason for triggering the nudge determines whether the activity or time frame is of primary concern. If nudging is triggered by the time interval from the last activity or by a committed schedule, the time for the next nudge is first selected. On the other hand, if a user activity pattern or an event triggers the nudge, the activity is selected first.

The objective of this step is to select a combination of activity and time that lead the nudge to be classified as probable. If a long-term nudge is to be designed, an unlikely activity may be selected, as this represents a long-term personal goal for the user.

Based on the available probable activities, the system can potentially design a set of nudges that are all useful. Therefore, we do not assume the existence of one correct nudge, only a set of probable nudges, from which one is selected and designed as the next nudge. Which one is chosen need not be vitally important. However, by monitoring user activity, over time the system may detect that certain activities are preferred by the user. Such activities may be given priority when selecting among the probable nudges. On the other hand, variation among suggested activities is needed. This is further discussed in Section 6.

5.3. Influence and Inform the User

After an activity and time are determined, motivational effect(s) and practical information supporting the activity is selected. Determining how to influence the user involves creating a digital choice environment that encourages or makes it easier for the user to choose the activity. The system selects an influence type, either by choosing freely among all available influences or by choosing influence(s) that previously have been successful for this user. One nudge can combine multiple influence types, e.g., by combining influences involving simplification, information, and affect.

One aspect of *simplification* is to provide practical information for an activity. Knowing, for example, the relevant opening hours, directions, and conditions (e.g., on a trail) can make it easier for a user to select the activity. Data from external sources are used both for simplification purposes and to support other types of influence. For example, an *affect* influence can include images collected from other users or the activity's web page, an *inform* influence can include health information about the positive effects of being active,

and an *incentive* or *loss aversion* influence can use information about bargains or availability of the activity.

For the next nudge, the system must identify essential and non-essential information. This depends on the selected activity and influence type as well as on how knowledgeable the user is with respect to the activity. It is crucial to provide the necessary information and not to overwhelm the user with already known information. Therefore, the selection of information is personalized based on what has previously been presented to the user.

5.4. Present the Nudge

When designing a nudge, information about an activity and motivational effects are combined and presented in a timely manner. As nudges should be easily available to the user, we present them on a readily available mobile device (typically, the user's mobile phone).

There are many guidelines for mobile applications and user interface design [16–18], and a nudging application should adhere to such guidelines where relevant. These guidelines handle challenges caused by the small size of mobile interfaces, use of relatively new interaction forms (such as touch screens and gestures), interactions that can happen almost anywhere, and interrupted usage.

In addition, the characteristics of smart nudging pose requirements as to nudge presentation. A nudge is a gentle push towards a nudging goal. This implies that we cannot expect the user to request a nudge actively, and must instead design the system to provide nudges automatically to the user. Therefore, the nudging system must first present a nudge as a push notification. Clicking on the notification brings the user to the application, where the complete nudge is presented.

As a complete nudge may include a lot of information, the nudging system distinguishes between essential and non-essential information and primarily presents the essential information. While non-essential information should be available, the user may need to explicitly navigate to it (e.g., by clicking a link).

A nudge's influence component originates in psychological effects for behavioral change. Thus, a smart nudging system must provide digital representations of the different influence types. Figure 3 shows two examples of how complete nudges might look. Both nudges suggest hiking trips. The nudge to the left includes textual information, the estimated time required, graphical elements showing the difficulty and length of the trip, and a link to more information. An image from the mountaintop and graphics for good weather are included to influence the user to take the trip (using the *affect influence* type). The nudge to the right uses a *social influence* by explaining that friends have completed a specific trip or by allowing the user to invite a friend to join a trip. These and other nudge examples show how psychological effects can be used in a smart nudge, and are reported on further in [19].

A push notification is, in most cases, a very short text appearing on a part of the mobile screen. To avoid it, the user can simply ignore the nudge. The notification should include an influence component. This means that a notification might display supportive text, include an image or emojis, or otherwise attract the user to see the complete nudge and ultimately proceed with the suggested activity.

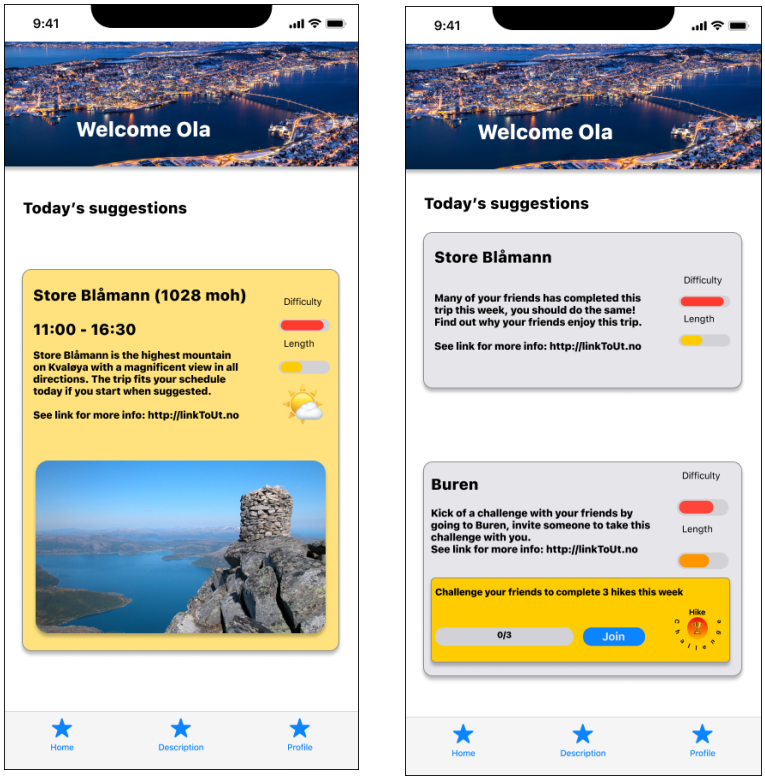

Figure 3. Examples of nudges for physical activity [19].

6. Principles of Smart Nudge Design

We have identified a set of novel principles of smart nudge design that should be followed by nudging systems. These principles, shown in Table 5 and described below focus on smart nudging and are relevant for designing personalized and context-aware nudges tailored to the user's specific needs. The principles are named *challenge the user, variation, consolidate, timeliness, avoid impossible nudges*, and *avoid annoying the user*.

Table 5. Principles for smart nudge design.

Principles	Description
Challenge the user	Select activities (type or length of activity) more challenging than the user's normal behavior. Thus, influencing the user to change behavior towards the nudging goal.
Variation	The user should over time be given a variety of nudges. To avoid making the nudging tedious and to probe for acceptable activities and effective influence types.
Consolidate	When improved behavior is detected, the goal may, for a time period, be to stabilize the user on the new activity level.
Progress	After stabilizing the user on an activity level for a time period, the user should be challenged again with the next step towards the nudging goal (or with an improved nudging goal).
Timeliness	A nudge should be given at a time when it is possible for the user to react on it and when the nudge can be effective.
Avoid impossible nudges	The user should never be given a nudge which is impossible for him/her to do.
Avoid annoying the user	Irritating or disturbing nudges should be avoided.

6.1. Challenge the User

When using nudging to support behavioral change, the goal is to *challenge the user* by gently suggesting behavior that goes beyond the user's preferred behavior. This implies that the nudging system must detect the current user behavior (through monitoring and/or user feedback) and use this as a basis for designing nudges that represent something new or more challenging for the user. The overall goal of such nudges is to make the user stretch towards better behavior.

When focusing on physical activity, the system can, for example, challenge the user to be more active by nudging the person to (i) be active more often, (ii) be active for a longer period, or (iii) engage in more challenging activities.

As user behavior changes over time, the nudging system must detect these changes and adapt nudging to ensure that the user continues to be gently challenged as behavior either improves or (at times) degrades.

6.2. Consolidate

At a certain point, the user may reach a level of behavior sufficient to fulfill the nudging goal. For example, for physical activity there are recommendations regarding how active persons in certain age groups should be [20]. When a person reaches his/her recommended activity level, the nudging system may stop challenging the user and enter a state where nudges are provided only to help the user to maintain the improved behavior. Here, this is described as the *consolidate* principle (see Section 6.2).

When improved behavior is detected, a personal nudging goal may (for a time) be to support the user in maintaining the improved behavior. This implies that, for this period, nudging is less about challenging the user and is rather about ensuring that the user continues at the same level of activity.

6.3. Progress

The period where the goal is to maintain the behavior of the user might be followed by a new challenge to further improve their behavior. We call this the *progress* principle. After stabilizing the user for a time period, they can be rechallenged with the next step towards their nudging goal or with an improved nudging goal.

6.4. Variation in Nudging

When nudging is triggered, there are potentially many probable nudges that are relevant for the user. The next nudge is therefore selected among a set of nudges, where different activities and influence types can be used.

Variation in nudging is a smart nudge design principle that has the objective of exposing the user to a variety of activities and influence types. The reason is twofold. First, variation is necessary to monitor user acceptance of different nudges to detect preferred activities and effective influences that can be prioritized in later nudges. As preferred activities and effective influences may change over time, nudge variation should continue during the use of the nudging system.

Second, variation is needed to make the nudging interesting and to enlighten the user about the variety of available activities. Variation in nudging can gently push the user to engage in new activities that the user may like and find inspiring.

6.5. Avoid the Impossible and the Annoying

As users are unable to follow nudges classified as impossible, these nudges should obviously be avoided. The impossibility of nudges is user-dependent, time-dependent, and situation-dependent, meaning that the set of impossible nudges changes over time for a specific user and varies between different users. Therefore, avoiding impossible nudges is highly dependent on personalization and knowledge of user capabilities, availability, and situation.

Annoying nudges are a fourth class of nudges which is much more challenging to determine compared to the three classes described in Section 4.1 (i.e., impossible, unlikely, and probable nudges). An annoying nudge may be described as irritating or disturbing; for example, it may be inappropriately timed, suggest an activity that has been rejected by the user several times already, or involve a presentation that makes it inefficient (by, for example, having too much or too little information). To avoid being annoying, nudges should be easy to follow and easy to avoid, and should not demand a lot of attention or interaction from the user.

Whether a nudge is annoying or not is user-dependent. It is, however, difficult to detect annoying nudges based on user monitoring. Therefore, for the nudging system to obtain precise information about what the user considers annoying, manual feedback from the user is required.

6.6. Timeliness

To be effective, a nudge should be provided in a timely manner. Timeliness means that the nudge should suggest an activity that is relevant with respect to the current situation of the user and has appropriate timing to support the user in reaching their nudging goal. This implies that the user should be nudged to perform the activity at a time that is suitable for them and that the activity should be needed to continue with improving their behavior toward the desired goal.

There are two important time frames for a nudge. The first is the time of nudging (i.e., the time the user is presented with the nudge), and the other is the suggested time for performing the selected activity. For example, a nudge at lunchtime can suggest going for a walk in the afternoon. A nudge must be timely with respect to both time frames.

7. Discussion

Personalization and context-awareness are central properties of a smart nudging system, and determining the next nudge is to a large extent about creating a nudge that is tailored to the individual receiving the nudge and his/her situation. A smart nudge has the potential to be more relevant to an individual user compared to a default (i.e., one-size-fit-all) nudge.

Personalization is generally described as the ability to provide tailored content and services to individuals based on knowledge about their preferences and behavior, and is a valuable tool for assisting users in searching, filtering, and selecting information of interest [21,22]. The main focus within nudging has up until recently been on one-size-fit-all nudges. However, in recent work, such as [23–25], the importance of personalization in designing effective nudges has been recognized. The work of [23,24] shows through experiments that personalized nudges can lead to increased nudging effectiveness compared to non-personalized nudges.

Contextual awareness for nudging concerns the ability of the nudging system to gather user context information at any time and provide nudges that are relevant to the user's current situation and environment. Context information is important for tailoring nudges, and can, for example, trigger a nudge (by detecting nice weather or available time for being active) or cause a nudge to be classified as impossible or unlikely (e.g., by detecting harmful air pollution, lack of time, or a traffic jam on the way to the activity).

Susceptibility to nudging is a significant concern when designing nudges; in our work, we find that personalization and context awareness can affect all components of a nudge, including activity, influence, content, time frame, and presentation. When designing the next nudge, the ability to perform the suggested activity is important. This is the focus of the classification presented in Section 4.1. According to Thaler and Sunstein, nudges should be easy to avoid, and options should not be removed [1]. Nevertheless, the nudging system should be designed to ensure that the nudges provided to the user are likely to be accepted. Therefore, we believe that an important aspect of nudging is to remove options

that are impossible for the user to follow. In this respect, we contradict the work of [25], where only the presentation of choices is personalized, not the choices themselves.

Concerning personalization, our work is more in line with [23], where a distinction is made between *choice personalization*, which determines what to nudge an individual for, and *delivery personalization*, which determines the most effective method of nudging an individual. However, we believe that both choice and delivery personalization must be combined to produce a truly personalized nudge. In addition, we consider context awareness and knowledge about the user's environment and situation as vitally important in supporting susceptibility and tailoring of nudges.

8. Conclusions

Using digital nudging to help people improve their behavior has great potential. In this paper, we have presented how personalized and context-aware smart nudges can be designed and how the next nudge for a person can be determined. Creating a next nudge that is tailored to a specific user is challenging, as the user's situation, profile, and level of behavior must be taken into consideration, and this situation is constantly changing. In this paper we have presented a novel classification of nudges that identifies currently relevant nudges for each individual user that are candidates to be the next nudge. This classification makes it possible to rule out *impossible* and *unlikely* nudges and focus on selecting the next nudge among the *probable* nudges, which represent activities the user is currently capable of.

We further describe the process of designing a smart nudge through several design steps. This includes a description of what triggers a nudge, which activity to suggest, timing, how to motivate the user to follow the nudge, and how to use practical information to make it easy for the user to follow through with the activity. Nudge design follows a set of principles, and in this paper we present a novel set of principles for the design of smart nudges. These principles focus on how to tailor and adapt the nudge to the specific user.

We are currently in the process of implementing an application for smart nudging which in order to test our principles for nudge design. The application will include user testing and evaluation of adaptive nudging with the presented classification and principles for smart nudge design.

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