Time Turner

Abstract

Temporal perception can be influenced by external Earth's rotation-based and social-based timetable, as well as people's internal biological-based timetable. We implemented a program called "time turner" that aims to help people who have difficulty aligning the two timetables, and verified the effect by conducting a user study. We analyzed the qualitative and quantitative results, and drew to the conclusion that the time turner has a promising future to be used in more applications, and to help people maintain a healthy daily routine and positive mental state.

Introduction

Our perception of time has two sources: external source, and internal source. The external source means the objective definition of time that is based on the Earth's rotation and is accepted by the general society. This objective time is defined in units of days, hours, minutes, and seconds. In people's modern daily life, the objective time can be acquired from various time displays, including phones, computers, clocks, and many other devices. Even long before those electric devices that is used to display the accurate time, people from ancient age are able to tell the time from the lighting of the sky, temperature in the air, noise level of the surrounding environment, etc. to tell the time of the day. The judging criterion of time is still the same among the history, which is based on the rotation of the Earth.

The internal source of the temporal perception is our biological clock. It tells us when to go to sleep, when to take a meal, etc., which is a subjective timetable that answers to the needs of the human body in order to survive and thrive. This temporal perception is less about accurate time, but more about doing certain activities in a timely and orderly manner, which is derived from the long history of evolvement and is recorded in the genes.

We depend on our objective timetable to schedule biological-based daily necessities, and then use the subjective timetable to better collaborate with each other and handle social duties. Therefore, how to combine the two timetables together is a necessary and

important issue in everyone's daily life. But this sometimes can be very challenging, because the subjective and objective temporal perception do not always align with each other, which could cause some difficulties in everyday life, sometimes even induce more serious mental problems. For example, for people whose biological circle is not 24 hours per day, which is called Non-24-hour syndrome or Non-24-hour disorder (non-24 as an abbreviation), maintaining a regular lifestyle within a 24-hour timetable is unreasonable and painful.

The misalignment between the internal and external source of time perception could also explain the reason why many people suffer from insomnia while constantly feeling sleepy during working hours, but they still have to keep themselves awake using reasonable mind or external stimulation like caffeine, tea, nicotine, etc. One of many explanations could be that their internal biological-based timetable misaligns with the external definition of time, leading to the scenario where it is night-time but their internal timetable does not catch up to the schedule for sleeping, and vice versa in the day time. These people are sometimes called "night owls" or "nocturnal people".

The modern society runs on the assumption that most people have an internal timetable that aligns with the external timetable, which means there is a commonly agreed external timetable for everyone to follow, for example, the most common working hour is during the daytime between 9am and 5pm, and the nighttime should be used to sleep. But when this assumption is accepted as consensus, the life of night owls can be very difficult. Many of them might sometimes feel they do not belong to the world when they stay wide awake during the night, wondering what's wrong about their internal timetable and even what's wrong about themselves.

But there is nothing wrong about them, or their internal timetable. The misalignment is not uncommon, and not untreatable. For people who live in the place where the external source of temporal perception is inaccessible, for example, the astronauts who live in the space stations, or people living in the poles where the lighting is either polar day or polar night, or people living in a dark room that is completely isolated from the outside world, a clock with displayed time would be a useful alternative external source of time perception. But unlike natural hint from the outside world, the displayed time does not necessarily have to be the same as the real time that is adopted by the rest of the world, which could function as a solution to help solve the misalignment.

Presumably, it would be useful to use algorithms to control the displayed time to align with people's internal timetable, while the corresponding real time aligns with the

external timetable. The principle of the approach can be understood as a “time storage bank”: when the displayed time is ahead of the real time, which is also when the internal timetable is ahead of the external timetable, it saves certain amount of hours for you so the brain and biological circle perceives these hours as time that is already past and spent, and then when the internal timetable falls behind the external timetable, the displayed time retrieves those previously saved hours to create an illusion that the two timetables align with each other, and therefore hopefully to help night owls to have a better experience of collaborating with other people, or to help non-24s to sleep better.

We verified this assumption by implementing a program called “time turner”, and conducting an experiment on one user who used to be a night owl.

Method

The program “time turner” includes two main parts: a frontend with an interface to display the manipulated time, and a backend with an algorithm that defines the mapping function between the internal timetable and the external timetable.

Frontend

The interface of the time turner is designed to be similar to the interface of most common commercialized electric clocks in the markets, trying to create an illusion that this is just another normal clock that displays real time, while in reality the displayed time is controlled by the backend algorithm. An example of the interface can be found in Fig. 1.

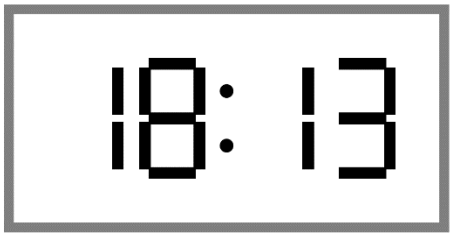

Fig. 1 Example of the interface

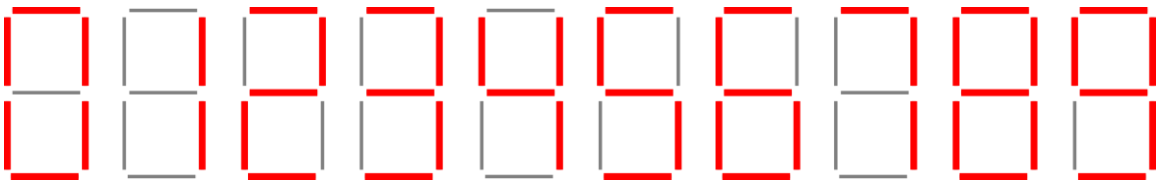

Fig. 2 Implementation of the interface

The implementation of the frontend interface is written in Python script. The surrounding edge of the interface and all the digits are plotted in Tkinter graphical tool, and the implementation of the digital display is shown in Fig. 2.

The displayed time accuracy is in the unit of minute, but the display of the frontend is updated every 20 seconds, making sure that in the situation of displayed time rate is different from the real time rate, (within a limitation of three times faster), the time turner still updates the time display every minute. The reason why the interface is not updated more frequently than every 20 seconds is out of the consideration of computational pressure and memory occupation of the computer.

Backend

The backend algorithm that maps the internal timetable to the external timetable is the core of the time turner program and the whole project. The mapping function is designed to be customizable, thus for each and every single individual, the mapping function can be different, and the customizing process is designed to be user-friendly.

The user-defined variable has four different variables: starting time point of each activity in the internal timetable, ideal starting time point of same activities in the external timetable, speed of time rate during the activity, the name of the activity.

As long as the user input the variables, the algorithm automatically displays the internal time point when the real time is the ideal time point, and then the displayed time rate will be the same as the defined speed of the time rate, until the next defined time point. The name of the activity is optional during input, but if it is inputted, the time turner will also display it on the interface along with the displayed time, to remind user of what to do during this period of time, which further reinforce the internal timetable for the brain.

Experiment

The experiment is targeted to test the possibility of shifting the daily routine of a nocturnal person to a timetable that is more aligned with the common timetable of society's expectation.

The test subject is a young female student (23 years old), and the testing time is the summer vacation of 2020, during which she doesn't have mandatory timetable-based duties.

The experiment is conducted in two periods: pre-experiment period and main experiment period. Both periods last for three weeks. During all six weeks, the starting and ending time point of the test subject's every activity is recorded and the activity is categorized into six classes: sleep, work, meal, write, chore, fun. This categorization is also customized to the test subject's usual daily activities, which can be further extended if the experiment is extended to test on wider group of users.

Pre-experiment Period

During the pre-experiment period, the test subject lives in a daily routine that accords to her biological habit, which reflects the original internal timetable and is later used as baseline for inputting variables in the mapping function.

After three weeks of pre-experiment, the recorded timetable shows that the test subject roughly follows same daily schedule every day in terms of six categories of the activity. The average result of starting and ending time point of each activity of pre-experiment is visually marked in the first line of Fig. 3.

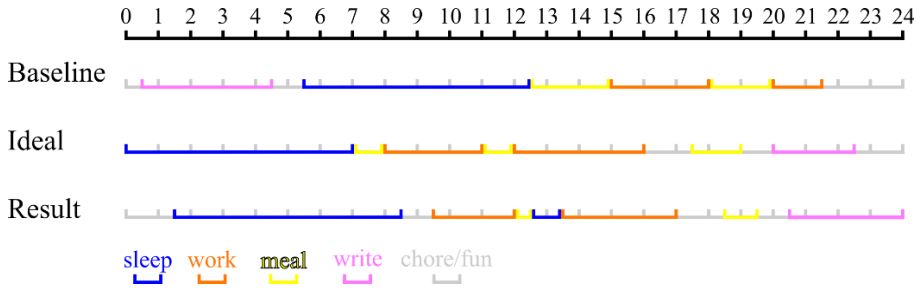

Fig. 3 Comparison of internal timetable and external timetable

Main Experiment Period

The target result of the experiment, which is the ideal timetable, is then raised by the test

subject herself and plotted in the second line of the Fig. 3.

The main differences between the baseline timetable and the ideal timetable, which are also the targeting results for the shift of timetable, are as follows:

1) Sleep: The bedtime shifts forward, while keeping the duration of sleeping the same.

2) Work: The main working hours shifts to align with the common working time of the society, and the total duration of working hours is expected to be longer.

3) Meal: Change two meals into three meals, and shorten the total time for meal.

4) Write: Shift writing hours forward, and shorten the total duration.

5) Chore/Fun: Not specifically plan ahead for chore or fun time, but most of the remaining time that can't fall into the previous four classes can be categorized into these two classes, which is hopefully to be shorter.

In this experiment, this ideal timetable is also specifically customized to the test subject, only to verify the possibility of modifying internal timetable using the time turner. If the experiment is extended to broader community, the ideal timetable should also be customized to each individual depending on their ideal lifestyle.

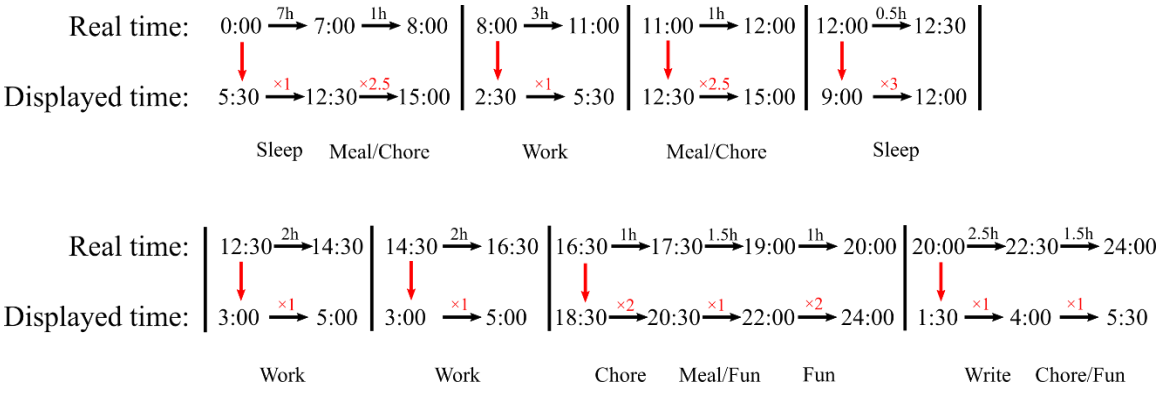

Fig. 4 Mapping function

According to the corresponding relationship between the baseline timetable and the ideal timetable, the mapping function is then generated as shown in Fig. 4. Each red arrow in Fig. 4 represents an incontinuous jumping time point in the time turner's interface, indicating the start of a new scheduled activity. The red number with small product sign means how much faster the speed of the displayed time rate is compared to the real time

rate. In general, the test subject hopes the time turner to show a faster time flow when it is scheduled to do something less important, such as for chore or fun, in order to achieve the targeting of squeezing these time.

Due to the accelerated time rate, the total amount of time of a day as displayed on the time turner is 30 hours, which interestingly achieves some common human fantasies of manipulating time to some extends.

During the three weeks of the main experiment period, all the other time displays in the living environment of the test subject are covered or hidden, and the curtain of the room is completely drawn all the time, to block any other external source of temporal perception, leaving time turner to be the only external time support.

The test subject lives according to the time hint and activity instruction on the time turner, and record all her categorized activities again. The result is half-quantitatively shown in the third line in Fig. 3. A more detailed analysis and discussion is in the result section.

Results

Quantitative results

		Starting time	Ending time	Duration	Total time
Sleep	Before	5:29	12:57	7:28	7:28
	After	1:26	8:23	6:57	7:49
		12:41	13:34	0:52	
Work	Before	15:01	17:49	2:47	7:51
		20:12	21:38	1:26	
		23:58	3:37	3:38	
	After	9:29	11:57	2:28	7:53
		13:48	16:58	3:09	
		21:07	23:23	2:16	
Write	Before	0:23	4:25	4:02	4:02
	After	20:34	0:01	3:26	3:26
Meal	Before	12:42	14:09	1:26	2:55
		20:13	21:43	1:29	
	After	11:59	12:35	0:36	1:39
		18:20	19:23	1:03	
Fun/Chore	Before				1:43
	After				3:13

Table. 1 Result of time turner experiment

The result of the experiment is very promising, according to intuitive understanding from

Fig. 3 and quantitative result from Table. 1. Some observations of the comparison of the result from the pre-experiment and main experiment are as follows:

1) Sleep: The average bedtime shifts forward around 4 hours. The average duration of night time sleep is shorter than baseline, which requires some afternoon naps as a compensation, making the total amount of sleeping time half an hour longer.

2) Work: The working time shifts to mostly mornings and afternoons, but due to the unexpected afternoon nap, the total daytime working duration is shorter, therefore the test subject uses extra time after dinner which is scheduled for writing to work. The overall results show that the total working time is almost the same.

3) Meal: Even though the ideal timetable schedule for three meals, during experiment, the test subject still returns to the old habit of having only two meals even though the time turner instructs otherwise. The total amount of time for meals is shorter than the baseline.

4) Write: Due to extra working hour in the night, the scheduled time for writing is squeezed, and the total amount of time for writing is about half an hour shorter compared to the original timetable. The ending time point of writing is also averagely later than the ideal timetable, causing the bedtime further pushed back.

5) Chore/Fun: The time for chore and fun is unexpectedly about 1.5 hours longer, which is not yet understood.

Qualitative feedbacks

During the experiment, the test subject also keeps a journal about her emotional feelings and other reflections that are not revealed from the quantitative results. Some notes from the journal are as follows:

Day 1: Get up too early, feel sleepy all day. Have to have a nap, so it takes up the lunch time, seems like a bad beginning of a vicious circle. Go to bed an hour later than what the clock says.

Day 2: Wake up in the night, feel like the whole night's sleep is all shallow sleep. Get up an hour later than what the clock says. The overall mental state is not bad.

Day 3: Become super sleepy at only 10pm (in real time). It normally won't happen. Feels as if the whole biological circle is shorten.

Day 4: Didn't sleep well in the night, wake up several times.

Day 5: The body seems to begin accustomed to the schedule a little bit more. Maybe wake up a few times in the night, can't remember.

Day 6: Sleep an hour later last night. A lot of bad dreams, sleep really uncomfortably, get up supper late, about 11am. Didn't hear the clock.

Day 8: Shallow sleep all night again.

Day 11: Still feel the sleep quality is not so good.

Day 13: Wake up an hour earlier than clock.

Day 14: Didn't have afternoon nap.

Day 15: The last night's bedtime and today's get up time are all two hours later than the clock. But the good thing is the breakfast becomes early lunch again, and the afternoon schedule can follow the clock.

Day 16: Similar schedule as yesterday. Everything is two hours later than the clock.

Day 20: Feels like the inspiration for creative writing can't be fooled by the clock. I didn't write well for these three weeks, at least as good or as much as I used to do when I can write in the late night. I feel I can't write unless it's deep in the night. It seems to have nothing to do with the external timetable, more like a built-in stubborn internal timetable.

The qualitative feedbacks don't seem to be as positive as quantitative results, but it also reveals some important messages that we can follow up with:

1) When the sleeping schedule is disturbed, even if the mind conceives the displayed time as the same bedtime as the baseline internal timetable, the body would still have some biological reactions to resist the change, for example, shallow sleep and constant wake-ups.

2) The internal timetable for artistic expressive work such as inspiration for creative writing might have a fixed time point that is irrelevant with the visual conception of time. It might also imply that, even in an environment without external source of temporal perception, there will still be a part of internal timetable that corresponds to the external timetable of the Earth's rotation, showing the close relationship between the human as a Earth-born species.

3) The overall mental state remains to be fairly good during the experiment, suggesting that the time turner not only contributes to the physical change of daily routine, but also have positive influence on mental health.

Discussion

Limitation

One major mistake during the experiment is that, the pre-experiment is conducted under the condition that the clocks are not hidden and the curtain is not drawn. Therefore, even though the test subject may think she is acting entirely according to her natural internal timetable, the external source of time is still influencing the time arrangement of her activities. This could explain the reason why the pre-experiment result shows roughly same daily routine, but the test subject self-identifies as a non-24. An updated pre-experiment should take similar actions during the main experiment period that all the external source of time perception should be blocked, including avoiding lightings and other subtle hints of real time.

Another limitation of the current time turner that is reflected from the qualitative feedback is that, the sudden change of the timetable makes the test subject really sleepy for a whole day in the first several days, and the sleeping quality in the following days is also doubtful. A possible reason is that the change is too drastic for the body to make adjustment in time, just like the tough situation after a long-distance flight and facing the jet lag. A potential solution is to use machine learning or other intelligent algorithms to control the mapping function to shift from baseline to the ideal timetable gradually every day. The slow process is expected to make the change easier for the body and internal timetable to adjust to.

Usage and applications

The initial targeting user scenario of the time turner is to help people adjust their daily routines. As stated in the introduction section, it is not uncommon for people to feel their internal timetable misalign with the external timetable, which leads to more social and mental problems. Especially during the global pandemic when people tend to live in isolation and is allowed to have a flexible daily routine, coordinating the timetable with other people and the common timetable of the society becomes increasingly difficult.

Therefore in this situation, the time turner can function as a helpful tool to keep people's daily routine on clock.

Another finding from the experiment result regarding mental health indicates that the time turner and the shifted aligned timetable is able to help people keep a positive mental state, since many night owls feel more isolated to the rest of the world, which could lead to depression, anxiety, and other mental disorders. By aligning their timetable to more people, a closer social connection network can be built based on timely communication, which hopefully help everyone to feel more connected and socially supported, especially during this tough time.

Future extension

The time turner can be combined with smart home system. Since during the experiment, one of the most important step is to hide all the other time displays in the living environment and draw all the curtains to block the external lightings to prevent mix-up from multiple discordant external source of temporal perception, by combing the time turner with smart home system can further achieve this goal. For example, if the lighting, the temperature, and the voice level in the living environment are all controlled by the same intelligent central housekeeper, which acts according to the time turner, then the overall experience of temporal perception would be more immersive and convincing. Therefore presumably, the effect of shifting daily routine and maintaining positive mental state should be more effective.

Conclusion

We implemented a program called "time turner" to help align people's internal biological-based timetable with the external Earth's rotation-based and social-based timetable. We verify the effect of the time turner by conducting a user study on a person who used to have a nocturnal timetable but wishes to shift the timetable forward. The mapping function of the time turner during the experiment is customized to the test subject. The result is analyzed both qualitatively and quantitatively, which shows a promising future extension to help people maintain a healthy daily routine and positive mental state.