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**Nudging and Health: An Experimental Study on Patients with Type 2
Diabetes**

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Abstract: Nudging, grounded in behavioral economics, refers to the systematic shaping of choice environments in ways that influence behavior without constraining individual autonomy. This study examines the effectiveness of a mobile application-based nudging intervention in supporting disease management among patients with Type 2 diabetes. Sixty patients were assigned to experimental and control groups and followed for six months under a controlled intervention design. In addition to routine clinical follow-up, patients in the experimental group received regular behavioral prompts integrated into daily monitoring. Changes in HbA1c, HDL, and LDL levels were assessed alongside indicators of health-related behavior. The intervention was associated with a marked improvement in metabolic outcomes. Relative to baseline, HbA1c levels declined by 1.988 units, HDL levels increased by 7.157 units, and LDL levels decreased by 37.751 units in the experimental group. Taken together, these findings demonstrate that digitally mediated nudging can meaningfully enhance chronic disease management and underline the relevance of behavioral economics for innovation in health-related organizational practices.

Keywords: *Behavioral Economics, Nudging, Health Innovation, Type 2 Diabetes, Digital Health.*

Introduction

According to the 2024 data of the International Diabetes Federation (IDF), there are 589 million adults aged 20-79 living with diabetes worldwide, and this number is projected to reach 853 million by 2050 (IDF, 2025). In addition, global health expenditures related to diabetes account for approximately 10% of total health spending, and diabetes ranks as the sixth leading cause of death in a major country such as the United States. Therefore, implementing preventive measures aimed at reducing the prevalence of diabetes is of critical importance (Cusick et al., 2005).

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Beyond medical complications, individuals with diabetes experience significant challenges in their social lives due to declines in quality of life. Restrictions on eating and drinking freely, limited participation in social activities, and reduced productivity in the workplace are among the most commonly reported problems. Moreover, out-of-pocket payments and additional healthcare expenditures place a considerable financial burden on patients. In a bibliometric analysis examining the economic impacts of diabetes costs, Tulan Tohumcu and Daştan (2024) identified the most frequently used keywords in the literature as diabetes cost, medication cost, diabetes types, quality-adjusted life years, and self-monitoring (Tulan Tohumcu & Daştan, 2024; Möllenkamp et al., 2019). In particular, self-monitoring behaviors among individuals with diabetes have emerged as a critical component of effective disease management, making this domain a key area for nudge-based interventions.

Kahneman et al. (1991) argue that economics traditionally assumes individuals possess stable, well-defined preferences and make consistent rational choices in markets, distinguishing it from other social sciences. However, economics is not independent of psychology and related disciplines (Kahneman et al., 1991). Building on this perspective, behavioral economics rejects the mainstream assumption of *homo economicus* and instead emphasizes the concept of bounded rationality. Bounded rationality refers to the limited cognitive capacity of the human mind, which leads to systematic difficulties in decision-making processes (Karagöl, 2020).

In their book *Nudge: Improving Decisions About Health, Wealth, and Happiness*, published in 2008 during the global financial crisis, Thaler and Sunstein argued for moving away from market models based on fully rational actors. This work laid the theoretical foundations of Nudge Theory (Thaler & Sunstein, 2008).

Nudges are defined as simple and low-cost interventions that aim to steer behavior in predictable ways by restructuring choice architecture, without restricting freedom of choice, banning options, or significantly altering economic incentives (Gane, 2021). By accounting for individuals' cognitive limitations, this approach seeks to support healthier and more beneficial decision-making.

In recent years, nudge-based interventions aimed at increasing treatment adherence and promoting healthy lifestyle behaviors among individuals with diabetes have become one of the most prominent and effective applications of behavioral economics in the health domain. Such interventions strengthen self-monitoring behaviors and contribute to sustainable and long-term gains in disease management (Voyer, 2015).

Original Contribution

Although the number of studies addressing behavioral interventions related to diabetes has been steadily increasing, experimental research with comparative and controlled designs remains limited in the existing literature. This study aims to move beyond conventional clinical approaches and traditional patient education by experimentally testing the applicability of behavioral economics theories to diabetes management. The comparative design incorporating a control group allows for a stronger identification of causal relationships, while also enabling the analysis of patients' responsiveness to different types of nudging interventions.

By intersecting behavioral economics with chronic disease management, the study offers a multidisciplinary contribution to the literature. In this context, it evaluates the effectiveness of nudging techniques implemented through an interactive, phone-based monitoring system for individuals diagnosed with Type 2 diabetes. Monitoring biochemical indicators such as HbA1c, HDL, and LDL over a six-month intervention period ensures that the findings are informative not only from a clinical perspective but also in terms of health policy design.

While framing, status quo bias, and gamification are among the most frequently examined nudging mechanisms in health-related research, this study focuses on relatively underexplored

approaches. Specifically, it tests deadline effects and social norm-based nudges, thereby demonstrating the potential effectiveness of alternative behavioral interventions in diabetes management.

Literature Review

Behavioral economics is a field that draws on concepts from economics and psychology to better understand and influence how individuals make decisions (Fanaroff et al., 2024). According to behavioral economists, individual behavior is shaped by moral norms and value judgments; therefore, individuals are not fully rational as assumed in classical economic theory. Individuals with bounded rationality rely on heuristic shortcuts, make systematic errors, and experience difficulties in accurately evaluating the costs and benefits of their choices (Kılıç, 2021). Consequently, individuals are prone to cognitive biases (Van Kleef et al., 2012). Within this framework, nudging has emerged as a subfield of behavioral economics that seeks to explain why people's short-term decisions systematically undermine their long-term interests and why observed behavior deviates from rational-choice models (Luoto & Carman, 2014).

A nudge aims to change behavior in a predictable way without prohibiting any options or significantly altering economic incentives. For an intervention to qualify as a nudge, it must be easy and inexpensive to opt out of. Nudges typically operate by modifying the underlying choice architecture, for example by changing default options. Unlike traditional policy instruments such as mandates, bans, or penalties, these interventions impose little to no material cost on individuals (Benartzi et al., 2017; Szollosi et al., 2025; Fajardo et al., 2024).

Nudge-based policies have been widely implemented in the field of health across many countries, including the United States, the United Kingdom, Japan, Denmark, Greece, and Türkiye, and their effectiveness has also been demonstrated in areas such as education, energy use, and savings behavior. According to OECD data from 2018, there are 202 behavioral insight teams worldwide (Aldemir & Kaya, 2020). Following the establishment of the United Kingdom's "nudge unit" in 2010, similar units were founded in countries such as Australia, Germany, the Netherlands, and Singapore. These units aim to design behavioral interventions that encourage desirable behaviors without restricting choice, to test them quickly and at low cost, and to scale up effective strategies (Benartzi et al., 2017).

Although the application of nudging to disease monitoring and treatment is relatively recent, its intervention methods have attracted considerable attention due to the benefits and convenience they offer (Afşar & Toker, 2021). Nudge-based interventions have been applied to a wide range of conditions, including chronic diseases (Möllenkamp et al., 2019), cardiovascular diseases (Fanaroff et al., 2024; Fajardo et al., 2024; Paluch et al., 2022), obesity (Li et al., 2021; Cunha et al., 2017; Forberger et al., 2024), cancer (Purnell et al., 2015; Jenssen et al., 2023; Wang et al., 2025), and diabetes (Cusick et al., 2005; Bjørngaas et al., 2008; Balducci et al., 2014; Gopalan et al., 2016; Fortmann et al., 2017; Hollands et al., 2018; Höchsmann et al., 2019; Kwan et al., 2020; Joachim et al., 2022; Tanaka, 2023; Kushwaha et al., 2025; Long et al., 2025). In the post-COVID-19 period, nudging has also been widely used to increase vaccination rates (Baştürk & Eken, 2020; Barbaroux et al., 2021; Johansen et al., 2024; Lassen et al., 2024).

The most commonly used nudging methods in disease treatment processes include reminders delivered via SMS (Fortmann et al., 2017; Lassen et al., 2024) or email messages (Benartzi et al., 2017; Lassen et al., 2024), social norms that allow individuals to compare their behavior with that of others (Bicchieri & Dimand, 2022), and gamification strategies based on reward and penalty systems (Sardi et al., 2017). Additionally, nudges such as default bias (Kroese et al., 2016), framing effects (Park et al., 2020; Ainiwaer et al., 2021; Gao et al., 2023), and status quo bias (Karl et al., 2019; Tentori et al., 2022) have been frequently employed. In contrast, the present study tests the effectiveness of relatively underexplored nudging

mechanisms-namely, deadline effects and social norm -based nudges- in the context of diabetes management.

Methodology

Study Population and Sample

The study population consisted of individuals diagnosed with Type 2 diabetes who attended the Internal Medicine Outpatient Clinic of Erzurum City Hospital. The sample comprised patients aged between 20 and 70 years who applied to the same outpatient clinic between 08.11.2024 and 04.12.2024, were examined by Assoc. Prof. Dr. Emine Kartal Baykan, and met the predefined inclusion and exclusion criteria (n = 60).

The adequacy of the sample size was assessed using G*Power software. The critical F value was calculated as 2.69. The F values obtained in the study (HbA1c = 6.428; HDL = 17.144; LDL = 5.780) exceeded this threshold, indicating that the time x group interactions could be detected with statistical significance. In addition, a power analysis based on test statistics reported in a study by Şimşek Çetinkaya (2018) with a similar experimental design indicated a minimum required sample size of 8 participants (4 experimental and 4 control). Accordingly, the current sample was confirmed to be sufficient in terms of statistical power.

Inclusion and Exclusion Criteria

- Diagnosis of Type 2 diabetes within the last year
- Age between 20 and 70 years
- HbA1c level of 7% or higher
- Ability to use a smartphone and access the internet
- At least primary school education and ability to communicate in Turkish
- Availability of home blood glucose monitoring devices

Exclusion Criteria

- Presence of diabetic retinopathy
- Presence of diabetic neuropathy
- Presence of diabetic nephropathy
- Presence of chronic diseases other than diabetes
- Pregnancy
- Mental or communication impairments

Participants who met the inclusion criteria were assigned to two groups, consisting of 30 individuals in the experimental group and 30 individuals in the control group. Both groups were followed for a period of six months. The experimental group received phone-based behavioral nudges, educational content, reminder messages, and social comparison tables. The control group received no additional intervention beyond routine outpatient follow-up.

At the beginning of the study, all participants were informed about the study protocol and procedures, and participation was based on voluntary consent. During this process, some participants agreed to take part only if assigned to the control group, citing the perceived length of the study period, while others (n = 7) chose to withdraw from the study for the same reason. It was observed that male participation rates were relatively low, whereas female participants reported feeling more comfortable participating due to the researcher being female. Although such preferences may be considered a factor affecting sample homogeneity, participants' autonomy was respected, and these dynamics did not compromise the randomization process during sample selection.

Research Hypotheses

- H1: Nudge-based visual materials and messages lead to improvements in patients' HbA1c, HDL, and LDL levels.

- H2: Nudge-based interventions increase patients' daily water consumption and step counts.
- H3: The deadline effect is effective in patients' adherence to routine follow-up controls.
- H4: Social nudging interventions in the experimental group are effective in increasing water consumption and step counts.

Data Collection Instruments

Sociodemographic Information Form

A form was developed in line with the relevant literature to determine participants' sociodemographic and clinical characteristics. The form included variables such as age, gender, educational level, marital status, type of treatment, medication adherence, regular physical activity, dietary compliance, and general health perception.

Metabolic Indicators

HbA1c, HDL, and LDL levels were measured at baseline (0 month), at the 3rd month, and at the 6th month under hospital laboratory conditions.

Intervention: Nudging Applications

1. Informational Nudges

Throughout the study period, participants in the experimental group received visual materials and videos via WhatsApp providing essential information about diabetes. The content covered topics such as basic knowledge of diabetes, diabetic nutrition, the diabetes treatment process, proper blood glucose measurement, insulin use, diabetes and physical activity, diabetes control, foot care in individuals with diabetes, and appropriate actions to be taken in cases of hypoglycemia and hyperglycemia. These materials aimed to enhance patients' knowledge and awareness without imposing any mandatory behavioral requirements.

2. Daily Routine Monitoring

Daily monitoring of patients was conducted based on three key indicators: water consumption (measured in number of glasses), regular medication use, and daily step counts. To measure step counts, participants were asked to install a pedometer application on their smartphones. In accordance with legal and ethical requirements, no specific application was recommended, and each participant used a pedometer application of their own choice. Participants in the experimental group received a standardized monitoring message via short message service (SMS) every day between 21:00 and 22:00. The content of the message was as follows: "Routine check time. Dear x, have you taken your medications and drunk your water today? Have you completed your walk?" Participants who responded to the message received positive feedback intended to reinforce healthy behaviors: "Congratulations. Our fight against diabetes is continuing in a healthy way. We will defeat diabetes." Participants who did not respond received a follow-up message at the end of the day (00:00) accompanied by a sad-face emoji, aimed at providing feedback: "We are sorry. Today, you did not report your step count, medication intake, or the number of glasses of water consumed." The primary rationale for adopting an interactive, phone-based monitoring approach was the widespread use and accessibility of mobile phone technologies across broad population groups, including low-income individuals and older adults. This approach enhances the accessibility and sustainability of patient follow-up while overcoming practical limitations of face-to-face healthcare services related to time, cost, and access. Mobile health (mHealth) applications facilitate continuous and bidirectional communication with patients, thereby supporting the monitoring and management of chronic diseases. In this context, SMS stands out as a simple and low-cost communication tool used by approximately three-quarters of global mobile users. Its high engagement rate is a key factor enhancing its effectiveness in patient monitoring, with approximately 99% of messages reported to be opened and around 90% read within the first three minutes after receipt. These features make SMS-based interventions particularly suitable

for frequent, daily, low-cost, and interactive behavioral interventions in chronic conditions such as diabetes (Fortmann et al., 2017).

3. Deadline-Based Intervention

Laboratory follow-up assessments were scheduled by assigning a fixed date three months after the baseline measurement. Patients in the experimental group additionally received reminders regarding their scheduled laboratory test dates. This design enabled the examination of the role of the deadline effect in treatment adherence. The corresponding table is provided in the Appendix.

4. Social Norm Intervention

The social norm intervention was inspired by the study of Costa and Kahn (2013), which demonstrated the effects of social comparison methods in promoting energy conservation. Accordingly, a “daily performance table” was prepared for patients. The first table was generated on 02.01.2025 and the second on 11.04.2025, and both were sent to participants as visual materials via WhatsApp. The accompanying message included the following note: “Good evening, Ms./Mr. ... While asking about your daily routines today, I would also like to share part of our study with you. The table presents daily scores of patients with diabetes similar to you. You are registered as Patient X. In my opinion, you are performing well / You could achieve a better score. ”This intervention aimed to create a social norm nudge by allowing patients to compare their own behaviors with those of their peers. The relevant tables are provided in the Appendix.

Statistical Analysis

Model Selection

Due to the longitudinal data structure consisting of repeated measurements at 0, 3, and 6 months for both the experimental and control groups, the analyses were conducted using Linear Mixed Models (LMMs). The model developed by Laird and Ware (1982) is widely applied in health sciences, as it accounts for within-subject correlations among repeated measurements. In this framework, the random-effects component captures within-individual variability, while the fixed-effects component explains group differences and time x group interaction effects.

Assumption Testing

The following diagnostic procedures were applied to assess model assumptions:

Normality of Error Terms: Histogram analysis, Q-Q plots, and the Kolmogorov-Smirnov test

Homogeneity of Variance: ZPRED-ZRESID scatter plot analysis

Results of Assumption Tests: Although minor deviations were observed in the Kolmogorov-Smirnov test for HbA1c and HDL, the Q-Q plots largely supported the assumption of normality. No violations were identified that would compromise the validity of the model. Overall, the assumptions of the Linear Mixed Model were adequately met, and LMM was determined to be an appropriate analytical approach for the present study.

Ethical Considerations

Ethical approval for the study was obtained from the Ethics Committee of Erzurum Technical University on 07.11.2024 (Decision No. 11) prior to the initiation of the research. Institutional permission was also granted by the administration of Erzurum City Hospital, where the study was conducted. In addition, written informed consent was obtained from all individuals with diabetes who agreed to participate in the study. This study was derived from the first author’s doctoral dissertation (Tulan Tohumcu, 2025).

Results

Table 1: Descriptive characteristics of the experimental and control groups

| Variable | Experimental Frequency | Experimental Percentage | Control Frequency | Control Percentage |
|----------------------------------|------------------------|-------------------------|-------------------|--------------------|
| Gender | | | | |
| Female | 19 | 63.3 | 22 | 73.3 |
| Male | 11 | 36.7 | 8 | 26.7 |
| Education Level | | | | |
| Primary School | 9 | 30.0 | 13 | 43.3 |
| Middle School | 3 | 10.0 | 7 | 23.3 |
| High School | 6 | 20.0 | 10 | 33.3 |
| Bachelor's Degree | 6 | 20.0 | 0 | 0.0 |
| Postgraduate Degree | 6 | 20.0 | 0 | 0.0 |
| Marital Status | | | | |
| Married | 25 | 83.3 | 13 | 43.3 |
| Single | 5 | 16.7 | 17 | 56.7 |
| Income Distribution | | | | |
| 20,000-40,000 | 4 | 13.8 | 13 | 43.3 |
| 41,000-60,000 | 12 | 41.4 | 11 | 36.7 |
| 61,000-80,000 | 7 | 24.1 | 3 | 10.0 |
| 81,000-100,000 | 1 | 3.4 | 2 | 6.7 |
| 101,000 and above | 5 | 17.2 | 1 | 3.3 |
| Expenditure on Medication | | | | |
| 435-735 | 4 | 13.8 | 6 | 20.0 |
| 736-935 | 8 | 27.6 | 6 | 20.0 |
| 936-1135 | 1 | 3.4 | 2 | 6.7 |
| 1136-1335 | 9 | 31.0 | 10 | 33.3 |
| 1336 and above | 0 | 0.0 | 6 | 20.0 |
| Type of Treatment | | | | |
| Insulin | 11 | 36.7 | 2 | 6.7 |
| Oral Antidiabetic Drugs | 19 | 63.3 | 28 | 93.3 |
| Regular Use of Medication | | | | |
| Yes | 16 | 53.3 | 17 | 56.7 |
| No | 14 | 46.7 | 13 | 43.3 |
| Diet Compliance | | | | |
| Yes | 9 | 30.0 | 11 | 36.7 |
| No | 21 | 70.0 | 19 | 63.3 |
| Regular Exercise | | | | |
| Yes | 6 | 20.0 | 5 | 16.7 |
| No | 24 | 80.0 | 25 | 83.3 |
| Health Status | | | | |
| Good | 8 | 26.7 | 5 | 16.7 |
| Moderate | 22 | 73.3 | 19 | 63.3 |
| Poor | 0 | 0.0 | 6 | 20.0 |

In the experimental group, 19 participants were female and 11 were male. In the control group, 22 participants were female and 8 were male (Table 1).

Income levels were classified based on income ranges determined with reference to the minimum wage. Accordingly, in the experimental group, 4 patients had a monthly income between 20,000-40,000 TL, 12 between 41,000-60,000 TL, 7 between 61,000-80,000 TL, 1 between 81,000-100,000 TL, and 5 had an income of 101,000 TL or above. In the control group, 13 patients were in the 20,000-40,000 TL range, 11 in the 41,000-60,000 TL range, 3 in the 61,000-80,000 TL range, 2 in the 81,000-100,000 TL range, and 1 patient had an income of 101,000 TL or above (Table 1).

Monthly expenditure levels for oral antidiabetic drugs and insulin used in diabetes treatment were also examined. In the experimental group, 4 patients reported monthly expenditures of 435-735 TL, 8 reported 736-935 TL, 1 reported 936-1135 TL, 7 reported 1136-1335 TL, and 9 reported expenditures of 1336 TL or higher. In the control group, 6 patients reported

expenditures of 435-735 TL, 6 reported 736-935 TL, 2 reported 936-1135 TL, 10 reported 1136-1335 TL, and 6 reported expenditures of 1336 TL or higher (Table 1).

In determining medication expenditures, market prices of oral antidiabetic drugs (Drug A: 432.83 TL; Drug B: 596.98 TL; Drug C: 612.22 TL) and insulin preparations (Brand A: 1118.16 TL; Brand B: 1111.34 TL; Brand C: 791.99 TL; Brand D: 978.46 TL) were taken as reference. These prices were obtained by the researcher from a randomly selected pharmacy on 07.01.2025 (Table 1).

When treatment modalities were examined, 11 patients in the experimental group were receiving insulin therapy, while 19 were using oral antidiabetic drugs. In the control group, 2 patients were treated with insulin and 28 patients were using oral antidiabetic medication (Table 1)

Table 2: Pairwise comparisons of hba1c levels across time points

| Groups | (I) Time | (J) Time | Mean Difference (I-J) | Standard Error | Sig. | 95% Confidence Interval | |
|---------------------|--------------------|--------------------|-----------------------|----------------|--------|-------------------------|--------|
| | | | | | | Lower | Upper |
| Experimental | Baseline | Second Measurement | 0.761 ^a | 0.499 | 0.129 | -0.224 | 1.747 |
| | | Third Measurement | 1.988 ^{a,*} | 0.509 | <0.001 | 0.983 | 2.992 |
| | Second Measurement | Baseline | -0.761 ^a | 0.499 | 0.129 | -1.747 | 0.224 |
| | | Third Measurement | 1.226 ^{a,*} | 0.526 | 0.021 | 0.188 | 2.265 |
| | Third Measurement | Baseline | -1.988 ^{a,*} | 0.509 | <0.001 | -2.992 | -0.983 |
| | | Second Measurement | -1.226 ^{a,*} | 0.526 | 0.021 | -2.265 | -0.188 |
| Control | Baseline | Second Measurement | -0.203 ^a | 0.485 | 0.676 | -1.161 | 0.754 |
| | | Third Measurement | -0.520 ^a | 0.485 | 0.285 | -1.477 | 0.437 |
| | Second Measurement | Baseline | 0.203 ^a | 0.485 | 0.676 | -0.754 | 1.161 |
| | | Third Measurement | -0.317 ^a | 0.485 | 0.515 | -1.274 | 0.641 |
| | Third Measurement | Baseline | 0.520 ^a | 0.485 | 0.285 | -0.437 | 1.477 |
| | | Second Measurement | 0.317 ^a | 0.485 | 0.515 | -0.641 | 1.274 |

Columns I and J represent the time variable, with values corresponding to the baseline, second, and third measurements presented in these columns. The mean differences reflect changes between measurement time points. A positive mean difference indicates that the value at time I is higher than the value at time J (Table 2).

In the experimental group, a statistically significant decrease of 1.988 units was observed between baseline and the third measurement ($p < 0.001$). This finding indicates that the intervention was effective over time. In contrast, the difference between baseline and the third measurement in the control group was 0.520 units and was not statistically significant ($p = 0.515 > 0.05$). Although baseline HbA1c levels were lower in the control group, HbA1c values increased at the second and third measurements (Table 2).

Table 3: Pairwise comparisons of hdl levels across time points

| Groups | (I) Time | (J) Time | Mean Difference (I-J) | Standard Error | Sig. | 95% Confidence Interval | |
|--------------|--------------------|--------------------|-----------------------|----------------|---------|-------------------------|--------|
| | | | | | | Lower | Upper |
| Experimental | Baseline | Second Measurement | -3.811*, ^b | 1.412 | 0.008 | -6.598 | -1.024 |
| | | Third Measurement | -7.157*, ^b | 1.439 | < 0.001 | -9.998 | -4.316 |
| | Second Measurement | Baseline | 3.811*, ^b | 1.412 | 0.008 | 1.024 | 6.598 |
| | | Third Measurement | -3.346*, ^b | 1.488 | 0.026 | -6.283 | -0.409 |
| | Third Measurement | Baseline | 7.157*, ^b | 1.439 | < 0.001 | 4.316 | 9.998 |
| | | Second Measurement | 3.346*, ^b | 1.488 | 0.026 | 0.409 | 6.283 |
| Control | Baseline | Second Measurement | 2.041 ^b | 1.372 | 0.139 | -0.667 | 4.749 |
| | | Third Measurement | 4.478*, ^b | 1.372 | 0.001 | 1.770 | 7.185 |
| | Second Measurement | Baseline | -2.041 ^b | 1.372 | 0.139 | -4.749 | 0.667 |
| | | Third Measurement | 2.437 ^b | 1.372 | 0.077 | -0.271 | 5.144 |
| | Third Measurement | Baseline | -4.478*, ^b | 1.372 | 0.001 | -7.185 | -1.770 |
| | | Second Measurement | -2.437 ^b | 1.372 | 0.077 | -5.144 | 0.271 |

In the experimental group, a statistically significant difference of -7.157 units was observed between baseline and the third measurement ($p = 0.001 < 0.05$). This indicates that the baseline value was lower than the value at the third measurement and that HDL levels increased by 7.157 units over time. Given that HDL levels are generally low in individuals with diabetes and that increases in HDL are considered clinically meaningful, this rise supports the positive effect of the intervention (Table 3).

In contrast, in the control group, a statistically significant difference of 4.478 units was observed between baseline and the third measurement ($p = 0.001 < 0.05$). Unlike the experimental group, this result indicates an unfavorable change in HDL levels over time in the control group (Table 3).

Table 4: Pairwise comparisons of ldl levels across time points

| Groups | (I) Time | (J) Time | Mean Difference (I-J) | Standard Error | Sig. | 95% Confidence Interval | |
|--------------|--------------------|------------------------|-----------------------|----------------|---------|-------------------------|--------|
| | | | | | | Lower | Upper |
| Experimental | Baseline | Second Measurement | 16.820 ^a | 8.569 | 0.051 | -0.096 | 33.737 |
| | | Third Measurement | 37.751 ^{a,*} | 8.735 | < 0.001 | 20.507 | 54.995 |
| | Second Measurement | Baseline | -16.820 ^a | 8.569 | 0.051 | -33.737 | 0.096 |
| | | Third Measurement | 20.931 ^{a,*} | 9.031 | 0.022 | 3.103 | 38.758 |
| | Baseline | -37.751 ^{a,*} | 8.735 | < 0.001 | -54.995 | -20.507 | |

| | | | | | | | |
|----------------|--------------------|--------------------|------------------------|-------|-------|---------|--------|
| | Third Measurement | Second Measurement | -20.931 ^{a,*} | 9.031 | 0.022 | -38.758 | -3.103 |
| | Baseline | Second Measurement | -0.867 ^a | 8.326 | 0.917 | -17.302 | 15.569 |
| | | Third Measurement | -3.233 ^a | 8.326 | 0.698 | -19.669 | 13.202 |
| Control | Second Measurement | Baseline | 0.867 ^a | 8.326 | 0.917 | -15.569 | 17.302 |
| | | Third Measurement | -2.367 ^a | 8.326 | 0.777 | -18.802 | 14.069 |
| | Third Measurement | Baseline | 3.233 ^a | 8.326 | 0.698 | -13.202 | 19.669 |
| | | Second Measurement | 2.367 ^a | 8.326 | 0.777 | -14.069 | 18.802 |

In the experimental group, a statistically significant difference of 37.751 units was observed between baseline and the third measurement ($p = 0.001 < 0.05$). Since the baseline value was higher than the value at the third measurement, this finding indicates that LDL levels decreased over time. Given that LDL is commonly referred to as “bad cholesterol” and elevated LDL levels are associated with increased cardiovascular risk, this reduction supports the positive effect of the intervention (Table 4).

In the control group, the difference between baseline and the third measurement was -3.233 units and was not statistically significant ($p = 0.698 > 0.05$). This finding suggests an upward trend in LDL levels in the control group (Table 4).

Discussion

In this study, the findings obtained for each hypothesis were evaluated within the framework of the behavioral economics and health literature. Overall, the results demonstrate that behavioral nudge-based interventions can generate significant effects on both biochemical indicators and health-related behaviors in the management of Type 2 diabetes.

In the experimental group exposed to nudging interventions, an average decrease of 1.988 units in HbA1c, an increase of 7.157 units in HDL, and a decrease of 37.751 units in LDL were observed. These findings support H1 and indicate that behavioral interventions can produce statistically significant and clinically meaningful effects on biochemical outcomes. The reported reduction in HbA1c is consistent with the findings of Selen and Polat (2023), who documented an approximately 2.32% decrease following a web-based Type 2 diabetes education intervention. Moreover, clinical guidelines published by the Turkish Society of Endocrinology and Metabolism (TEMD, 2023) report that even pharmacological treatments often yield HbA1c reductions that do not exceed 1%. From this perspective, the 1.988-unit reduction achieved solely through behavioral nudges represents a noteworthy effect size with important implications for clinical practice.

A steady increase in average daily water consumption and step counts was observed in the experimental group from the beginning to the end of the intervention period, thereby supporting H2. At baseline, the experimental group consumed an average of 10.05 glasses of water per day and recorded 7,860 steps. These figures increased to 11.25 glasses of water and 11,655 steps at the midpoint of the intervention, and further rose to 11.75 glasses and 15,015 steps by the end of the study. Although the transition to the summer season may have contributed to the increase in step counts, the sustained upward trend suggests a meaningful effect of the behavioral intervention.

Participants’ verbal statements were also consistent with the quantitative findings. Individuals who previously lacked regular water consumption habits reported adopting this

behavior, while patients who did not engage in physical activity described walking as a “fun form of exercise” and indicated that they increased their walking frequency in order to improve their daily scores on the pedometer application. These observations suggest that behavioral feedback mechanisms strengthened intrinsic motivation.

As noted by Karyađdı (2021), reminders used in health appointments and daily health behaviors reduce cognitive load and enhance behavioral compliance. Consistent with this view, reminder-based nudges in the present study significantly increased water consumption and physical activity levels in the experimental group.

Findings related to the deadline effect support H3. In the experimental group, 22 patients complied with the scheduled laboratory tests during the second three-month period, and 25 complied during the third period. In contrast, only one patient in the control group completed laboratory tests on time during the second period, and none did so during the third period. These results align with existing literature emphasizing that deadline setting reduces procrastination and increases engagement in health-related processes.

After patients in the experimental group were presented with tables summarizing their past performance, marked increases in water consumption and step counts were observed, supporting H4. These findings are consistent with Allcott and Rogers (2014), who demonstrated that social comparison-based feedback effectively promotes behavior change. Clear, simple, and comparative feedback appears to facilitate more conscious and consistent decision-making among individuals.

Beyond the stated hypotheses, the study also revealed economically and clinically meaningful individual-level gains. Of the 11 patients in the experimental group who were using insulin at baseline, 4 transitioned to oral antidiabetic therapy by the end of the study. The economic implications of this shift indicate monthly savings of 4,472.64 TL for insulin Brand A, 4,445.36 TL for Brand B, and 3,167.96 TL for Brand C. Overall, insulin-related costs were reduced from a range of 8,711-12,224 TL to 5,543-7,779 TL. These findings suggest that nudge-based interventions have the potential not only to improve clinical outcomes but also to reduce the economic burden of diabetes management.

Individual-level behavioral changes further illustrate the multidimensional impact of the intervention. For example, one participant chose to walk to work, resulting in monthly savings of 1,196 TL and total savings of 7,176 TL over six months. Another participant reduced body mass index from 28.29 to 26.54 through dietary and physical activity changes. A patient who initially disliked exercise increased daily step counts to 7,000-8,000 and reduced HbA1c levels from 12.1 to 8.8. Additionally, a participant who used the pedometer application as a gamification tool developed a regular exercise habit, providing a concrete example that supports Sunstein’s (2014) concept of “fun nudges.”

Throughout the study, changes in dietary habits -such as reduced tea and bread consumption- were also observed as a result of behavioral feedback. Toward the end of the intervention, some participants expressed disappointment that the study was concluding and wished to maintain contact with the researcher. This reaction suggests that nudging interventions may function not only as behavioral tools but also as psychosocial support mechanisms, consistent with the concept of “behavioral commitment” discussed in the literature.

Conclusion

the behavioral interventions implemented in this study positively influenced a wide range of health outcomes, including medication adherence, physical activity, dietary habits, blood glucose monitoring, and biochemical markers such as HbA1c, HDL, and LDL levels, as well as overall quality of life. The findings indicate that context-specific nudge strategies, when appropriately designed and tailored to the target population, have strong potential to sustainably

improve health behaviors among individuals with Type 2 diabetes. At the same time, the study highlights two critical determinants of nudge effectiveness: the mode of delivery and communication of the intervention and the sociodemographic and clinical characteristics of the target patient group. Consideration of these factors provides an important roadmap for enhancing the effectiveness and sustainability of future behavioral economics–based health policies.

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Appendices

Table 5: Experimental and control Group Patient Analysis Follow-up Days

| | | | | | | |
|---|------------|---------------------------|------------|------------|---------------------------|---------------------------|
| | | | | | | |
| 1 | 20.11.2024 | 20.02.2025 | 20.05.2025 | 08.11.2024 | 07.02.2025/21 .02.2025 | 07.05.2025/08 .05.2025 |
| 2 | 20.11.2024 | 20.02.2025 | 20.05.2025 | 08.11.2024 | 07.02.2025/03 .03.2025 | 07.05.2025/05 .05.2025 |
| 3 | 21.11.2024 | 21.02.2025 | 21.05.2025 | 11.11.2024 | 10.02.2025/07 .03.2025 | 09.05.2025/30 .04.2025 |
| 4 | 27.11.2024 | 27.02.2025 | 27.05.2025 | 11.11.2024 | 10.02.2025/05 .03.2025 | 09.05.2025/20 .05.2025 |
| 5 | 21.11.2024 | 21.02.2025/26 .02.2025 | 21.05.2025 | 12.11.2024 | 11.02.2025/02 .01.2025 | 12.05.2025/29 .05.2025 |
| 6 | 22.11.2024 | 21.02.2025/20 .02.2025 | 22.05.2025 | 12.11.2024 | 11.02.2025/18 .02.2025 | 12.05.2025/14 .05.2025 |

| | | | | | | |
|----|------------|---------------------------|---------------------------|------------|---------------------------|---------------------------|
| 7 | 22.11.2024 | 22.02.2025 | 22.05.2025 | 13.12.2024 | 12.02.2025/18 .03.2025 | 13.05.2025/20 .05.2025 |
| 8 | 22.11.2024 | 22.02.2025 | 22.05.2025 | 14.11.2024 | 13.02.2025/07 .02.2025 | 14.05.2025/21 .05.2025 |
| 9 | 22.11.2024 | 21.02.2025/19 .02.2025 | 22.05.2025 | 14.11.2024 | 14.02.2025/26 .02.2025 | 15.05.2025/30 .04.2025 |
| 10 | 25.11.2024 | 25.02.2025 | 23.05.2025 | 14.11.2024 | 14.02.2025/17 .02.2025 | 15.05.2025/29 .04.2025 |
| 11 | 29.11.2024 | 29.02.2025 | 27.05.2025/12 .05.2025 | 15.11.2024 | 17.02.2025/24 .02.2025 | 16.05.2025/22 .05.2025 |
| 12 | 25.11.2024 | 25.02.2025/28 .02.2025 | 23.05.2025 | 18.11.2024 | 17.02.2025 | 16.05.2025/21 .04.2025 |
| 13 | 25.11.2024 | 25.02.2025 | 23.05.2025 | 18.11.2024 | 17.02.2025/26 .02.2025 | 16.05.2025/22 .04.2025 |
| 14 | 25.11.2024 | 25.02.2025 | 23.05.2025 | 18.11.2024 | 17.02.2025/06 .01.2025 | 16.05.2025/25 .04.2025 |
| 15 | 26.11.2024 | 26.02.2025/19 .02.2025 | 26.05.2025 | 18.11.2024 | 17.02.2025/04 .03.2025 | 16.05.2025/26 .04.2025 |
| 16 | 27.11.2024 | 26.02.2025 | 26.05.2025 | 19.11.2024 | 18.02.2025/27 .02.2025 | 20.05.2025/06 .05.2025 |
| 17 | 28.11.2024 | 28.02.2025 | 27.05.2025/13 .05.2025 | 20.11.2024 | 19.02.2025/05 .03.2025 | 20.05.2025/12 .05.2025 |
| 18 | 28.11.2024 | 28.02.2025/10 .02.2025 | 27.05.2025/16 .05.2025 | 06.12.2024 | 06.03.2025/25 .03.2025 | 06.06.2025/16 .05.2025 |
| 19 | 28.11.2024 | 28.02.2025 | 27.05.2025/20 .05.2025 | 06.12.2024 | 06.03.2025/21 .03.2025 | 06.06.2025/23 .05.2025 |
| 20 | 03.12.2024 | 04.03.2025 | 05.06.2025/20 .05.2025 | 09.12.2024 | 07.03.2025/02 .04.2025 | 09.06.2025/20 .05.2025 |
| 21 | 29.11.2024 | 03.03.2025 | 03.06.2025 | 09.12.2024 | 07.03.2025/03 .03.2025 | 09.06.2025/22 .05.2025 |
| 22 | 29.11.2024 | 03.03.2025 | 03.06.2025 | 09.12.2024 | 07.03.2025/24 .01.2025 | 09.06.2025/23 .05.2025 |
| 23 | 02.12.2024 | 04.03.2025 | 03.06.2025 | 10.12.2024 | 10.03.2025/18 .03.2025 | 10.06.2025/16 .05.2025 |
| 24 | 02.12.2024 | 03.03.2025/26 .02.2025 | 04.06.2025 | 11.12.2024 | 11.03.2025/18 .02.2025 | 11.06.2025/15 .05.2025 |
| 25 | 02.12.2024 | 03.03.2025/28 .02.2025 | 04.06.2025 | 11.12.2024 | 11.03.2025/07 .01.2025 | 11.06.2025/09 .05.2025 |
| 26 | 03.12.2024 | 04.03.2025 | 04.06.2025 | 11.12.2024 | 11.03.2025/20 .02.2025 | 11.06.2025/22 .05.2025 |
| 27 | 03.12.2024 | 04.03.2025 | 04.06.2025 | 12.12.2024 | 12.03.2025/19 .03.2025 | 12.06.2025/06 .05.2025 |

| | | | | | | |
|-----------|------------|------------|------------|------------|---------------------------|---------------------------|
| 28 | 03.12.2024 | 04.03.2025 | 04.06.2025 | 13.12.2024 | 13.03.2025/10 .04.2025 | 13.06.2025/08 .05.2025 |
| 29 | 04.12.2024 | 04.03.2025 | 04.06.2025 | 13.12.2024 | 13.03.2025/14 .03.2025 | 13.06.2025/20 .05.2025 |
| 30 | 04.12.2024 | 04.03.2025 | 05.06.2025 | 13.12.2024 | 13.03.2025/25 .03.2025 | 13.06.2025/22 .05.2025 |

| Patients | | | | | | | | | | | | |
|----------------------|-------|-----------------|----------|-------|-----------------|----------|-------|-----------------|----------|-------|-----------------|----------|
| | Water | Number of steps | Drug Use | Water | Number of steps | Drug Use | Water | Number of steps | Drug Use | Water | Number of steps | Drug Use |
| Experiment 1 | 5 | 3381 | Use | 6 | 3697 | Use | 5 | 2907 | Use | 6 | 4258 | Use |
| Experiment 2 | 9 | 1100 | Use | 12 | 4021 | Use | 8 | 2500 | Use | 10 | 3000 | Use |
| Experiment 3 | 4 | 2100 | Use | 6 | 3750 | Use | 6 | 3658 | Use | 8 | 3500 | Use |
| Experiment 4 | 7 | 8054 | Use | 9 | 9758 | Use | 8 | 8890 | Use | 10 | 10274 | Use |
| Experiment 5 | 6 | 2300 | Use | 8 | 5000 | Use | - | - | - | 5 | 2014 | Use |
| Experiment 6 | 8 | 5200 | Use | 9 | 6201 | Use | 8 | 4526 | Use | 12 | 4321 | Use |
| Experiment 7 | 4 | 3500 | Use | 8 | 5010 | Use | 7 | 3568 | Use | 7 | 3562 | Use |
| Experiment 8 | 4 | 4250 | Use | 5 | 1000 | Use | 8 | 4569 | Use | 8 | 2547 | Use |
| Experiment 9 | 8 | 1547 | Use | 8 | 5728 | Use | 6 | 2896 | Use | 8 | 4789 | Use |
| Experiment 10 | 8 | 7200 | Use | 10 | 7500 | Use | 16 | 12950 | Use | 18 | 13000 | Use |
| Experiment 11 | 4 | 5066 | Use | 9 | 7590 | Use | 7 | 1327 | Use | 8 | 3456 | Use |
| Experiment 12 | 4 | 3000 | Use | 8 | 3168 | Use | 5 | 1500 | Use | 5 | 2003 | Use |
| Experiment 13 | 2 | 307 | Use | 3 | 1655 | Use | - | - | - | 6 | 1257 | Use |
| Experiment 14 | 6 | 3615 | Use | 7 | 5730 | Use | 8 | 3554 | Use | 9 | 5879 | Use |
| Experiment 15 | 4 | 3546 | Use | 6 | 3285 | Use | - | - | - | 8 | 3689 | Use |

| | | | | | | | | | | | | |
|----------------------|---|------|-----|---|------|-----|----|-------|-----|----|-------|-----|
| Experiment 16 | 7 | 2789 | Use | 9 | 3897 | Use | 12 | 1254 | Use | 15 | 5674 | Use |
| Experiment 17 | 6 | 1475 | Use | 7 | 3254 | Use | 6 | 587 | Use | 7 | 3968 | Use |
| Experiment 18 | 7 | 7895 | Use | 8 | 7021 | Use | 10 | 12785 | Use | 12 | 13586 | Use |
| Experiment 19 | 5 | 2465 | Use | 6 | 2547 | Use | 8 | 3500 | Use | 5 | 2685 | Use |
| Experiment 20 | 4 | 3125 | Use | 6 | 3357 | Use | 4 | 5695 | Use | 5 | 6662 | Use |
| Experiment 21 | 5 | 2415 | Use | 6 | 2054 | Use | 9 | 4081 | Use | 9 | 4285 | Use |
| Experiment 22 | 8 | 3365 | Use | 8 | 4752 | Use | 8 | 6012 | Use | 9 | 8567 | Use |
| Experiment 23 | 6 | 2547 | Use | 6 | 1475 | Use | 8 | 1137 | Use | 7 | 1050 | Use |
| Experiment 24 | 7 | 6524 | Use | 7 | 5874 | Use | 4 | 1678 | Use | 6 | 2658 | Use |
| Experiment 25 | 4 | 654 | Use | 2 | 421 | Use | 4 | 562 | Use | 4 | 1235 | Use |
| Experiment 26 | 3 | 1879 | Use | 4 | 1425 | Use | 3 | 219 | Use | 3 | 589 | Use |
| Experiment 27 | 2 | 1513 | Use | 4 | 1879 | Use | 4 | 563 | Use | 5 | 2587 | Use |
| Experiment 28 | 8 | 4265 | Use | 8 | 4127 | Use | 8 | 3709 | Use | 10 | 6897 | Use |
| Experiment 29 | 3 | 657 | Use | 4 | 1258 | Use | 4 | 4256 | Use | 6 | 8795 | Use |
| Experiment 30 | 6 | 7238 | Use | 7 | 7508 | Use | 6 | 3659 | Use | 7 | 7412 | Use |