Hand(y) Hygiene Insights: Applying Three Theoretical Models to Investigate Hospital Patients' and Visitors' Hand Hygiene Behavior

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Abstract

Background

Improving hand hygiene is the most efficient method to prevent healthcare-associated infections, which are a severe threat to patient safety. Besides healthcare professionals, it is mainly hospital patients and visitors who pose a risk for the transmission of pathogens, which can lead to infections. In contrast to medical staff, laypeople's hand hygiene behavior in hospitals is not well researched. Therefore, the present study had three aims: 1) Identifying a suitable theoretical model to explain laypeople's hand hygiene practice; 2) Finding the factors that strongly affect patients' and visitors' hand hygiene behavior and, therefore, should be targeted in behavior change interventions; and 3) Comparing the essential determinants of hand hygiene behavior between laypeople and healthcare professionals.

Methods

To accomplish these goals, in total $N = 1{,}605$ patients and visitors were surveyed on their hand hygiene practice in hospitals. The employed questionnaires were based on three theoretical models: a) the Theory of Planned Behavior (TPB); b) the Health Action Process Approach (HAPA); and c) the Theoretical Domains Framework (TDF). Structural equation modeling (SEM) was used to analyze the data.

Results

Among patients, 53% of the variance in the hand hygiene behavior was accounted for by the TDF domains, 44% by a modified HAPA model, and 40% by the TPB factors. Among visitors, these figures were 60%, 37%, and 55%, respectively. Two clusters of variables surfaced as being essential determinants of the behavior: First, self-regulatory processes (perceived behavioral control; action control; memory, attention, and decision processes); and second, social influence processes (subjective norm and role and identity).

Conclusions

The TDF was identified as the most suitable model to investigate and predict patient's and visitor's hand hygiene practices. The critical determinants for adequate hand hygiene (i.e., self-regulation processes and social influence processes) are similar for laypeople and healthcare professionals. Therefore, analogous intervention strategies might be useful for both target groups. Further practical and theoretical implications are discussed.

Background

Worldwide, healthcare-associated infections pose a severe threat to patients' health and put massive financial constraints on health systems (1). The European Centre for Disease Prevention and Control estimated that 3.2 million patients were affected by healthcare-associated infections at European acute care hospitals in 2011–2012 (2). In an earlier report, it was projected that healthcare-associated infections directly cause approximately 31.000 deaths, contribute to another 111.000 deaths, and cost about EUR 7 billion annually (3).

Improving hand hygiene behavior has been confirmed as an efficient method to prevent healthcare-associated infections. Sanitizing hands with alcohol-based hand rub, which is the World Health Organization's (WHO) gold standard for hospital hand hygiene in most cases, inhibits the spread of pathogens and reduces the risk of infection (4–6).

Contaminated healthcare workers' hands are known as the most common vehicle for the transmission of pathogens causing healthcare-associated infections (5). However, several studies have shown that both patients and hospital visitors carry multidrug-resistant and other pathogenic organisms on their hands as well (7–9). Therefore, laypeople are a risk factor for the transmission of pathogens that can lead to infections. To this day, patients' and hospital visitors' hand hygiene behavior is not well researched. Laypeople are most likely an underestimated factor in infection prevention (10). In one study, patients and their relatives were encouraged to sanitize their hands twice a day, and as a result, methicillin-resistant *Staphylococcus aureus* (MRSA) infections decreased by 51%. Similar positive results were found at a psychiatric facility in which patients had to sanitize their hands every four hours to prevent respiratory virus infection outbreaks (10).

Little is known about how often and in what situations patients and visitors sanitize their hands in hospitals. One reason for the deficiency of research on laypeople's hand hygiene could be the lack of universally valid guidelines that indicate when these people should sanitize their hands in healthcare facilities (11). Four critical moments for patients have been proposed: (a) before and after touching wounds/devices; (b) before eating; (c) after using the restroom; and (d) when entering or leaving the patient room (12). Other scholars suggested a more comprehensive list with nine moments for patients' hand hygiene, which also included "after coughing, sneezing, or touching nose or mouth" and "before and after interacting with visitors" (11). Visitors should sanitize their hands at least before and after contact with a patient or the patient's surroundings (13). Given the lack of generally accepted guidelines for laypeople, it is not surprising that observed hand hygiene rates vary considerably in published studies. Rates range from 0.5% of visitors at a hospital entrance hall (14) to 56.0% and 57.3% of patients and visitors, respectively, at two hospital wards (15). One survey found that the majority of patients stated to "always" or "usually" clean their hands after toileting (84%) and before eating (72%), but other critical moments were not reported (16). Despite the variation, all studies show that there is room for improvement. Considering the aforementioned substantial effects of increasing patients' and visitors' hand hygiene rates on reducing infections (e.g., 10, 17), improving laypeople's hand hygiene behavior should be a priority to enhance patient safety.

One strategy to improve hand hygiene among laypeople could be to copy interventions to increase compliance with WHO guidelines among healthcare personnel. However, it cannot be taken for granted that facilitators and barriers to adequate hand hygiene are the same for healthcare professionals and laypeople. Increasing evidence suggests that tailored interventions based on theories and empirical findings are more effective in changing peoples' behavior (18–20). Therefore, determinants for laypeople's hand hygiene behavior in healthcare facilities should be systematically identified and used to design interventions.

However, identifying a theoretical basis to explain behavior is a complex task itself. There is an abundance of health-behavior theories, often with overlapping constructs (21, 22). Therefore, one goal was to find a suitable model as a base to design effective interventions for improving laypeople's hand hygiene in hospitals. To accomplish this, three theoretical models were tested: a) the Theory of Planned Behavior (TPB, (23)); b) the Health Action Process Approach (HAPA (24, 25)); and c) the Theoretical Domains Framework (TDF (21, 26)). These models were chosen because they have been used to study healthcare workers' hand hygiene behavior previously. Using the same models allows a comparison between healthcare professionals and laypeople. Below, an introduction to the three theoretical models is provided.

Theory Of Planned Behavior

The TPB is a classic health behavior theory (27) and the most widely cited model to explain hand hygiene behavior among healthcare workers (28). For the example of hand hygiene, the TPB postulates that a person's *intention* to clean their hands is the immediate antecedent for behavior. Moreover, the person's intention is predicted by three variables: First, by the *attitude towards the behavior*, which is formed by beliefs about the positive and negative outcomes of performing hand hygiene, and the evaluation of these outcomes. Second, by the *subjective norm*, shaped through perceptions about normative expectations of significant others regarding hand hygiene and a person's motivation to comply with these. And finally, by a person's *perceived behavior control (PBC)*, which is formed through beliefs about the ease or difficulty involved in performing hand hygiene (23, 29). A favorable attitude, salient social norm, and strong perceived control should lead to the intention to perform adequate hand hygiene.

A series of papers investigating relevant factors for healthcare workers' hand hygiene behavior reported significant correlations between the three pre-intention TPB variables (attitude, norm, and PBC) and the self-reported hand hygiene behavior (30–32). None of these three studies reported an intention measure. In three similar studies, only subjective norm and PBC emerged as relevant predictors for self-reported hand hygiene (29, 33, 34). At the same time, a survey among medical students found attitude and PBC, but not subjective norm, to influence self-reported compliance (35). When objectively observing compliance, one study found that none of the TPB variables but only the intensity of activity in the unit was negatively associated with hand hygiene (29). However, other scholars reported attitude and PBC to predict observed adherence (30), while yet another study found support for all TPB variables (36). Overall, there is evidence for the relevance of all TPB model-components to predict hand hygiene behavior among healthcare workers. However, PBC emerged as being of particular importance. In the studies that measured and included intention, the construct was crucial, but it never completely predicted all variance in behavior (29, 36). The phenomenon that intention does not always translate into action is known as the 'intention-behavior-gap' (37) and is one of the main causes for criticism of the TPB (e.g., 38).

Health Action Process Approach

To overcome the intention-behavior gap, the HAPA differentiates between a *pre-intentional motivational phase*, in which intention is formed, and a *post-intentional volition phase* that leads up to action (25, 38). In the pre-intentional phase, intention has three antecedents: *Risk perception*, which consists of the perceived likelihood of experiencing a negative outcome in relation to the behavior, and perceived severity, which is the degree of harm arising from the negative outcome; *Outcome expectancies*, which is an assessment of the benefits and disadvantages of the action; and *Perceived task self-efficacy*, which is the discerned capability of performing the behavior (25, 38). Regarding hand hygiene, this means perceiving the risk of pathogen transmission as high, expecting that hand cleaning reduces this risk, and believing in one's capability of adhering to guidelines, will lead to the intention to perform adequate hand hygiene. After the intention is formed, it needs to be reinforced by post-intentional processes. The two main processes are *planning* and, again, *self-efficacy* (38). Two types of planning act as mediators between intention and behavior: *action planning*, which includes details about the "when", "where," and "how" to act; and *coping planning*, which comprises strategies on how to overcome anticipated barriers to the action. Post-intentional self-efficacy can be distinguished into two beliefs: *maintenance self-efficacy*, which are optimistic beliefs about the capability to overcome barriers during the maintenance period; and *recovery self-efficacy*, which represents beliefs about the ability to regain control after a setback. This means that after the intention to perform hand hygiene is formed, the likelihood for it to translate into action increases if the person has a plan on when, where, and how to clean their hands and how to overcome potential constraints like an empty hand-rub dispenser. Additionally, the likelihood further increases if the person is optimistic about overcoming barriers and believes that compliant behavior can be restored even after a violation of the guidelines before. Further *barriers (e.g., environmental constraints) and resources (e.g., social support)* can influence the intention, planning, and actual behavior. Finally, *action control*, which comprises of self-regulatory effort, self-monitoring, and awareness of behavioral standards to adjust their behavior, is the last determinant in the volition phase (39, 40).

The HAPA has been applied to study hand hygiene behavior before. The PSYGIENE project (PSYchologically optimized hand hyGIENE promotion) was implemented to improve compliance among healthcare workers with an intervention based on the HAPA (41). Healthcare workers completed a HAPA-based questionnaire to identify the relevant targets for the intervention. Unfortunately, it is not known how the entire model predicted healthcare workers' behavior, but several findings were published. First, a strong belief among staff members that hand hygiene prevents pathogen transmission, was associated with high self-efficacy, high positive outcome expectations, and a strong intention to perform hand hygiene (42). Social resources in the form of cooperation at the ward, maintenance self-efficacy, and action control were significant predictors for self-reported hand hygiene compliance among physicians. Among nurses, only action control was significantly associated with hand hygiene behavior (43). These results indicate that post-intentional factors might play a role in overcoming the intention-behavior gap. They also show that relevant factors for engaging in behavior can vary between target groups. However, it remains unclear how much variance in hand hygiene can be explained by the HAPA model. A longitudinal study examined motivational and volitional factors for laypeople's handwashing, however, outside the healthcare context (39). They found support for the HAPA model but without including risk perception, as well as barriers and resources. Self-efficacy and outcome expectancies were associated with handwashing intention. Intention, action and coping planning were indirectly associated with handwashing via action control. However, it remains unknown if these results will translate to hand hygiene behavior in hospitals.

Theoretical Domains Framework

Other scholars have argued that focusing on only one theory, such as TPB or HAPA, to explain behavior is too narrow and leaves much variance unexplained (26, 44). Relying on only one theory has two main drawbacks: First, the researcher or practitioner needs to be able to identify a theory that is relevant to the behavior out of the abundance of existing models. Second, the selected theory might miss critical theoretical domains pertinent to the action (21). To overcome these issues, an expert team developed a consensus on which theoretical constructs are relevant for behavior change. The result is known as the Theoretical Domains Framework: a validated, integrative framework based on 33 theories and 128 constructs (21, 26). Originally, 12 theoretical domains were identified: 1) *knowledge*, 2) *skills*, 3) *social/professional role and identity*, 4) *beliefs about capabilities (self-efficacy)*, 5) *beliefs about consequences (anticipated outcomes)*, 6) *motivation and goals (intention)*, 7) *memory, attention, and decision processes*, 8) *environmental context and resources*, 9) *social influences (norms)*, 10) *emotions*, 11) *behavioral regulations*, and 12) *nature of behavior* (21). In a validation process, the framework was refined (26); however, in a subsequent attempt to develop a generic TDF-based questionnaire, scholars argued to keep the original version (45). The framework was developed to examine the implementation of evidence-based practice, but not to ascertain “the causal processes that link theoretical constructs in a coherent explanation of behavioral regulation or behavioral change” (21: p. 31). For the hand hygiene example, this means that every domain could be relevant for predicting people’s behavior, but not all of them have to. No formal path structure of how the domains interact to determine peoples’ behavior is proposed.

The TDF has been used to identify barriers and levers to behavior change across various actions, including healthcare workers’ hand hygiene. One study examined “real-time” explanations for non-compliance with guidelines reported by staff (44). More than three-quarters of the explanations came from 3 of the 12 domains. Among this 42% belonged to the domain memory, attention, and decision processes (i.e., forgetting, being distracted or prioritizing another task), followed by 26% for the domain knowledge (i.e., lack of knowledge about guidelines), and 9% for the domain environmental context and resources (i.e., lack of time or availability of products). Two surveys among care works identified social/professional role and identity (i.e., what is expected of healthcare professionals), beliefs about consequences (i.e., transmission risks), and knowledge as the most important facilitators for adequate hand hygiene (46). They also found that environmental context (i.e., time pressure, workload, and environmental controls), memory, attention, and decision processes, and beliefs about consequences to be the main barriers for compliance (46). Another study looked at patients’ hand hygiene behavior using qualitative data from a survey and interviews, and coded the responses according to the TDF (16). They found that the four most relevant domains for patients’ hand hygiene behavior were knowledge; environmental context and resources; memory, attention, and decision processes; and social influences (i.e., social norms). It is noteworthy that forgetfulness was identified as a primary barrier for adequate hand hygiene in all three TDF-studies. However, memory and attention processes are not even included in other theories like the TPB and HAPA. This finding backs the concern that when relying solely on one model, critical theoretical domains might be overlooked (21).

Method

Research Aims

The scope of the present paper was threefold: 1) to test whether path analyses, specified according to TPB, HAPA, and TDF fit the data well and to identify the model that can explain the most variance in hospital patients’ and visitors’ self-reported hand hygiene behavior; 2) to find critical determinants of patients’ and visitors’ self-reported hand hygiene behavior; and finally, 3) to compare these essential determinants of hand hygiene behavior in hospitals between laypeople and healthcare professionals. Surveys were conducted to look at patients and visitors separately. The results of the present study should help hospital hygiene practitioners to design and evaluate future interventions to improve patients’ and visitors’ hand hygiene behavior in hospitals.

Participants

Overall,the data of N = 1,605 patients and visitors recruited in four German hospitalswere analyzed for the present study. Participants missing more than 30% of the survey items were excluded from the analysis. Thus, the data from 845 patients(age ranged18 to 93 years; M = 55.72, SD = 16.78;51.13% female) and 760 visitors (age ranged 18 to 91 years; M = 50.10, SD = 16.48; 56.91% female) were included in the analysis. Overall,19 people did not report their gender, and 37 did not report their age. All participants were informed about the purpose of the study and gave informed consent.

Design and Procedure

The study followed a cross-sectional design. Visitorswere approached in the hospitals’ lobbieswhile patients were approached in their rooms and asked to participate in the survey. The wards for the patient survey were pre-selected to ensure a diverse mix of patients. Units covered almost the entire medical spectrum except for pediatric and palliative wards. The survey was conducted from December 2017 to November 2019. Subjectswere randomly assigned to one questionnaire (TPB, HAPA,or TDF). Participants were asked to complete the surveyat the hospital andhand it back to the investigators or to a nurse at the unit.

Materials

The first section of all questionnaires was identical both for visitors and patients. Itincluded information about the purpose of the study, instructions, and demographic questions. The questionnaires for the visitors included twoitems about theirtypical hand hygiene behavior in a hospital. The two items assessed whether they usuallysanitize their hands (a)before and (b) after contact with a patient on a 5-point scale adopted from previous research(43) ranging from1 (always) to 5 (rarely).These twomoments were chosen as the dependent variablebecause they are suggested in the literature(13). Moreover, one of the hospitals, in which the survey was conducted, placedthese indications in their guidelines for visitors. The patientquestionnaireincluded eight items about theirtypical hand hygiene behavior at the hospital at the following moments: (a) after entering and (b) before leaving the patient room, (c) before eating, (d) after using the restroom, (e) before and after touching wounds or medical devices, (f) before and after contact with mucous membranes, (g) after coughing or sneezing, and (h) before entering a high-risk area such as anintensive care unit.These eight indications were selected as the dependent variable because they are suggested in the literature(11). Again, one of the hospitals, in which the survey was conducted, placed these indications in their guidelines for patients. The behavioral variables were assessed on a 6-point scale ranging from 1 (always) to 6 (never). The sixth option was included in the patient survey after a few participants in the precursorvisitor surveymentioned there should be a neveranswer option. All questionnaire items afterward varied depending on the theoretical model. The structure of the patient and visitor questionnaires was the same but adjusted for the target group. All instruments were pre-tested for face-validity and clarity of the items with samples of at least 15 participants outside the hospital environment. The TPB-questionnaire was constructed according to a manual, as suggested in the literature(47). AConfirmatory Factor Analysis (CFA) was performed for each target group to ensure that all items included in the scales to measure the latent variables of the TPB model had at least a standardized factor loading of 0.40. Items with lower standardized factor loadings were dropped. The data fitted well with the original four-factor TPBstructure. The Supplementary Table 1 in Additional File 1 depicts the key measures of each questionnaire, item examples, as well as scale statistics. The items for the HAPA-questionnairewereadopted from the PSYGIENE project(48) but had to be adjusted to fit thelaypeople's sample. Again, a CFA was performed for each target group to ensure that all items included in the scales to measure the latent variables of the HAPA models have at least a standardized factor loading of 0.40. According to the CFAs, risk perception did not load onto a single factor but should be separated into perceived likelihood and perceived severity. Additionally, outcome expectancies had to be divided into positive and negative outcome expectancies, while all self-efficacy items loaded on a single factor. The resource- and inverted-barrier-items did not load on a single factor, and the barrier-items also did not load well on a separate factor. Therefore, the barriers-construct was dropped. Finally, the items for the TDF-survey were adopted from a questionnaire to investigate the barriers and levers to healthcare workers' hand hygiene behavior based on the TDF(49)and adjusted to fit the purpose of the present study. Their questionnaire combined the domains knowledge and skills and dropped the domain nature of behavior. Again, CFAs for each target group were performed to ensure that all items included in the scales to measure the latent variables in the TDF models have at least a standardized factor loading of 0.40.The data fitted sufficiently well with the original 10-factor structure suggested(49).

Data Analysis

All analyses were doneinR version 3.5.3.The path analyses to test the associations between each models' sociocognitive variables and people's hand hygiene behavior were performed using the package lavaan version 0.6-3(50). The models were fitted using a robustmaximum likelihood estimation (MLF), accounting for some non-normality in the datawith full information maximum likelihood (FIML) for missing data. There is no selection of model fit-indexes as well as cutoff levels that areuniversally agreed on to report path analyses. Wedefaulted to use the most commonly reported indexes and to rely on cutoff levels for a good model fit suggested in the literature (e.g., 51, 52):χ^2 /df ≤ 2 to 3, Root Mean Square Error of Approximation(RMSEA)< .06 to .08 with confidence intervals, Standardized Root Mean Square Residual(SRMR)≤ .08, Comparative Fit Index(CFI) ≥ .95, andTucker Lewis Index(TLI) ≥ .95. Also, we used theAkaike Information Criterion (AIC) andBayesian Information Criterion(BIC) for model comparison where the rule 'the smaller, the better' applies. If the majority of these fit indexes imply a good fit, we regard the model to fit the data well. The study's pre-registration, data, and R-script will be made available online upon publication:https://osf.io/m2v56/

Results

Self-Reported Hand Hygiene Behavior

The patients' mean level of self-reported hand hygiene behavior was M = 4.08 (SD = 1.24), and the visitors' mean level of self-reported hand hygiene behavior was M = 3.71 (SD = 1.28). Overall, both patients and visitors reported to *frequently* sanitize their hands in the hospital when averaging their respective indications for hand hygiene (eight indications for patients and two for visitors). Figure 1 showed the participants' responses separated for the indications surveyed.

TPB – Patients

The hypothesizedTPB path structure fits the data well:$\chi2$ = 5.25, df = 2, $\chi2$ /df = 2.63,p = .072, RMSEA = .08 with 90%-CI [.00, .16], SRMR = .02, CFI = .99, and TLI = .97. Figure 2shows the standardized parameter estimates with corresponding standard errors and confidence intervals displayed in Table 1. Attitude, subjective norm, and PBC accounted for 52% of the variance in patients' behavioral intention. Intention and PBC explained 40% of the variance in self-reported hand hygiene behavior among hospital patients.

Table 1
Coefficients for the TPB path model (patients)

					95% CI for β	
Path	β	*SE*	*z*	*p*	LL	UL
Attitude → Intention	0.20	0.07	0.20	.003	0.07	0.33
Subjective Norm → Intention	0.18	0.04	0.18	< .001	0.10	0.25
PBC → Intention	0.62	0.06	0.62	< .001	0.50	0.75
Intention → Behavior	0.56	0.07	0.56	< .001	0.43	0.69
PBC → Behavior	0.15	0.07	0.15	.041	0.01	0.29
Note. β = standardized coefficient, *SE* = standard error; *z* = β */SE, p* = probability value, LL = lower limit, UP = upper limit						

TPB – Visitors

The hypothesized TPB path structure fits the data well: $\chi2$ = 4.02, df = 2, $\chi2$ /df = 2.01, p = .134, RMSEA = .06 with 90%-CI [.00, .16], SRMR = .02, CFI = .99, and TLI = .98. Figure 3 shows the standardized parameter estimates for the TPB model with corresponding standard errors and confidence intervals displayed in Table 2. Attitude, subjective norm, and PBC accounted for 53% of the variance in visitors' behavioral intention. Intention and PBC explained 55% of the variance in self-reported hand hygiene behavior among hospital visitors.

Table 2
Coefficients for the TPB path model (visitors)

					95% CI for β	
Path	β	*SE*	*z*	*p*	LL	UL
Attitude → Intention	0.22	0.06	3.77	<.001	0.10	0.33
Subjective Norm → Intention	0.26	0.05	5.30	<.001	0.16	0.36
PBC → Intention	0.42	0.05	7.64	<.001	0.31	0.52
Intention → Behavior	0.22	0.04	5.46	<.001	0.14	0.30
PBC → Behavior	0.51	0.06	9.00	<.001	0.40	0.62
Note. β = standardized coefficient, *SE* = standard error; *z* = β */SE, p* = probability value, LL = lower limit, UP = upper limit						

HAPA – Patients

The initially hypothesized HAPA path structure does not fit the data particularly well: $\chi2$ = 83.14, df = 11, $\chi2$ /df = 7.56,p< .001, RMSEA = .16 with 90%-CI [.13, .19], SRMR = .05, CFI = .80, TLI = .57, AIC = 2375.12, and BIC = 2442.40. Accordingly, the model was modified post hoc. Thinking about the nature of hand hygiene behavior, hospital patients most likely do not engage in considerable planning on "when", "where", and "how" to clean their hands,noron how to overcome any anticipated barriers to performing hand hygiene. Therefore, the constructplanning was removed from the model. Additionally, the variable action control was allowed to correlate both with the self-reported hand hygiene behavior as well as intention, since the correlation between these variables is high and the modification improved the model fit substantially. This is also supported by previous research (39). The new model fits the data well:$\chi2$ = 8.63, df = 4, $\chi2$ /df = 2.16,p = .071, RMSEA = .07 with 90%-CI [.00, .13], SRMR = .02, CFI = .99, TLI = .95, AIC = 1332.98, and BIC = 1386.10. Also, the new model outperforms the original model significantly (p< .001). Figure 4shows the standardized parameter estimates for the adjusted HAPA model with corresponding standard errors and confidence intervals displayed in Table 3. Self-Efficacy, positive and negative outcome expectancies, risk perception (likelihood and severity), environmental resources, and action control accounted for 52% of the variance in patients' behavioral intention. Self-Efficacy, intention, environmental resources, and action control explained 44% of the variance in self-reported hand hygiene behavior among hospital patients.

Table 3
Coefficients for the HAPA path model (patients)

					95% CI for β	
Path	β	*SE*	*z*	*p*	LL	UL
Self-Efficacy → Intention	0.24	0.04	6.64	<.001	0.17	0.31
Pos. Out. Exp. → Intention	0.15	0.07	2.13	.033	0.01	0.28
Neg. Out. Exp. → Intention	0.03	0.06	0.54	.589	-0.09	0.15
Likelihood → Intention	0.08	0.05	1.68	.092	-0.01	0.16
Severity → Intention	0.14	0.04	3.35	.001	0.06	0.22
Resources → Intention	0.09	0.04	2.30	.021	0.01	0.17
Action Control → Intention	0.25	0.04	6.41	<.001	0.18	0.33
Self-Efficacy → Behavior	-0.02	0.05	-0.52	.604	-0.11	0.07
Intention → Behavior	0.41	0.07	5.59	<.001	0.26	0.55
Resources → Behavior	-0.03	0.05	-0.48	.632	-0.13	0.08
Action Control → Behavior	0.35	0.06	6.35	<.001	0.24	0.46

Note. β = standardized coefficient, SE = standard error; z = β /SE, p = probability value, LL = lower limit, UP = upper limit

HAPA – Visitors

As with the patients, the initially hypothesized HAPA path structure does not fit the data particularly well:$\chi2$ =173.66, df = 11, $\chi2$ /df = 15.79,p = <.001, RMSEA = .24 with 90%-CI [.21, .27], SRMR = .08, CFI = .47, TLI = -.16, AIC = 2735.68, and BIC = 2803.11. Accordingly, the model was modified posthoc. The same model modifications as with the patient data were performed. The new model fits the data well:$\chi2$ = 3.06, df = 4, $\chi2$ /df = 0.77,p = .547, RMSEA = <.001 with 90%-CI [.00, .08], SRMR = .01, CFI = 1.00, TLI = .1.00, AIC = 1559.36, and BIC = 1612.60. Also, the new model outperforms the original model significantly (p< .001). Figure 5shows the standardized parameter estimates for the adjusted HAPA model with the corresponding standard errors and confidence intervals displayed in Table 4. Self-Efficacy, positive and negative outcome expectancies, risk perception (likelihood and severity), environmental resources, and action control jointly accounted for 49% of the variance in visitors' behavioral intention. Self-Efficacy, intention, environmental resources, and action control together explained 37% of the variance in self-reported hand hygiene behavior among hospital visitors.

Table 4
Coefficients for the HAPA path model (visitors)

					95% CI for β	
Path	β	*SE*	*z*	*p*	LL	UL
Self-Efficacy → Intention	0.21	0.06	3.32	.001	0.09	0.34
Pos. Out. Exp. → Intention	0.11	0.05	2.31	.021	0.02	0.21
Neg. Out. Exp. → Intention	-0.03	0.09	-0.29	.769	-0.21	0.16
Likelihood → Intention	0.10	0.04	2.34	.019	0.02	0.19
Severity → Intention	0.02	0.06	0.37	.714	-0.10	0.15
Resources → Intention	0.01	0.05	0.17	.868	-0.10	0.12
Action Control → Intention	0.59	0.06	9.26	<.001	0.47	0.72
Self-Efficacy → Behavior	0.03	0.05	0.54	.592	-0.07	0.12
Intention → Behavior	0.51	0.07	7.11	<.001	0.37	0.65
Resources → Behavior	-0.04	0.05	-0.77	.438	-0.14	0.06
Action Control → Behavior	0.01	0.07	0.11	.911	-0.13	0.14
Note. β= standardized coefficient, *SE* = standard error; *z* = β */SE*,*p* = probability value, LL = lower limit, UP = upper limit						

TDF – Patients

The hypothesized TDF model is just-identified (i.e., equal numbers of variables and parameters with a unique solution). Therefore, the model fits the data perfectly, and there is no need to report fit indices. Figure 6shows the standardized parameter estimates for the TDF model with corresponding standard errors and confidence intervals displayed in Table 5. All social-cognitive variables together explained 53% of the variance in self-reported hand hygiene behavior among hospital patients.

Table 5
Coefficients for the TDF path model (patients)

					95% CI for β	
Path	β	*SE*	*z*	*p*	LL	UL
Knowledge/Skills → Behavior	0.04	0.06	0.81	.420	-0.06	0.15
Role and Identity → Behavior	0.27	0.04	6.27	<.001	0.18	0.35
Capability → Behavior	0.05	0.03	1.88	.060	0.00	0.10
Consequences → Behavior	0.04	0.05	0.85	.394	-0.05	0.13
Motivation/Goals → Behavior	0.22	0.07	3.02	.003	0.08	0.36
Memory/Attention → Behavior	-0.15	0.04	-3.94	<.001	-0.22	-0.07
Environment → Behavior	0.05	0.05	1.13	.257	-0.04	0.14
Social Influences → Behavior	0.06	0.05	1.22	.223	-0.04	0.16
Emotions → Behavior	0.16	0.04	3.76	<.001	0.08	0.24
Beh. Regulations → Behavior	0.03	0.04	0.74	.459	-0.05	0.10
Note. β= standardized coefficient, *SE* = standard error; *z* = β */SE*,*p* = probability value, LL = lower limit, UP = upper limit						

TDF – Visitors

Again, since the hypothesized TDF model is just-identified, it fits the data perfectly, and there is no need to report fit indices. Figure 7shows the standardized parameter estimates for the TDF model with the corresponding standard errors and confidence intervals displayed in Table 6. All social-cognitive variables together explained 60% of the variance in self-reported hand hygiene behavior among hospital visitors.

Table 6
Coefficients for the TDF path model (visitors)

					95% CI for β	
Path	β	*SE*	*z*	*p*	LL	UL
Knowledge/Skills → Behavior	0.12	0.05	2.46	.014	0.02	0.22
Role and Identity → Behavior	0.32	0.06	5.38	<.001	0.20	0.43
Capability → Behavior	0.08	0.05	1.45	.147	-0.03	0.18
Consequences → Behavior	0.06	0.05	1.21	.225	-0.03	0.15
Motivation/Goals → Behavior	0.09	0.05	1.88	.060	0.00	0.19
Memory/Attention → Behavior	-0.32	0.04	-7.09	<.001	-0.40	-0.23
Environment → Behavior	0.03	0.03	1.06	.288	-0.03	0.09
Social Influences → Behavior	0.08	0.04	1.88	.060	0.00	0.16
Emotions → Behavior	0.09	0.04	2.14	.033	0.01	0.18
Beh. Regulations → Behavior	-0.07	0.04	-1.84	.066	-0.13	0.00

Note. β= standardized coefficient, *SE* = standard error; *z* = β */SE,p* = probability value, LL = lower limit, UP = upper limit

Discussion

Summary Goal One: Finding a Suitable Behavioral Model

The first goal of the present study was to identify a theoretical model that is suitable for explaining the self-reported hand hygiene behavior of hospital patients and visitors. This was achieved by conducting an extensive survey among patients and visitors in four German hospitals using questionnaires based on the TPB, HAPA, and TDF. All three models proved useful for the task of examining laypeople's hand hygiene practice in hospitals. Among patients, 53% of the variance in the self-reported hand hygiene behavior during their hospital stay was accounted for by the TDF domains, 44% by the modified HAPA model, and 40% by the TPB factors. Among visitors, these figures were 60% (TDF), 37% (HAPA), and 55% (TPB) of explained variance in self-reported hand hygiene before and after patient contact.

During the model fitting process, it became clear that the HAPA model, in its original form, was not ideal for examining laypeople's hand hygiene behavior in hospitals. The HAPA is a stage model of health behavior change with a pre-intentional motivational phase, in which the behavioral intention is formed, and a post-intentional volition phase leading from the aim up to action (25, 38). According to the HAPA model, action and coping planning act as mediators between intention and behavior (38, 53). However, for the patients and visitors surveyed in the study, these planning processes did not emerge as mediators. Our first assumption on why planning did not fit in the model was due to the role laypeople's hand hygiene in healthcare facilities has played in the past. Researchers and hospital hygiene specialists have only comparatively recently begun to pay attention to laypeople as a potential vector for transmitting pathogens causing infections. Therefore, attempts to include them in the hospital's infection prevention strategy are still at an early stage. Consequently, we expected many surveyed participants to place themselves in the pre-intention phase due to the lack of awareness that they should clean their hands at the moments specified for them. The HAPA questionnaire included a state of change item also used in previous research (48). Surprisingly, the majority of both patients (73.4%) and visitors (80.3%) positioned themselves in the post-intentional action stage, which also corresponds to their high level of self-reported hand hygiene behavior. This indicates that laypeople are aware that they should clean their hands regularly in the hospital and report doing so. However, this finding makes it harder to explain why the planning constructs seemed irrelevant for this target group. A second explanation could lie in the crossectional nature of the study. Some of the planning items convey more meaning in longitudinal research, in which participants try to change their behavior deliberately. Therefore, the HAPA model should be reexamined within a behavior change intervention among laypeople. A third explanation might be the nature of the behavior, as already mentioned in the results section. Being hospitalized is usually a straining and anxiety-afflicting situation for patients and their relatives. Therefore, it might be that adequate hand hygiene is not a priority for most patients and their visitors. Consequently, laypeople probably do not plan on “when”, “where”, and “how” to clean their hands, nor on how to overcome barriers. It is intuitively plausible that the planning constructs do not fit in the model for this particular behavior and target group. Including action and coping planning as determinants for behavior might only be relevant if the person is motivated to change their actions.

Both the TPB and the TDF model fitted the data well without changes to the proposed structure. TDF was created “to simplify and integrate a plethora of behavior change theories and make theory more accessible to, and usable by, other disciplines” (26: p. 2). It is no causal model of behavior and does not include mediation pathways, which would indicate a causal direction of how its domains are related to each other and the behavior in question. The model fit of a just-identified model with equal numbers of variables and parameters with a unique solution is inevitably perfect, and the results are identical with a linear multiple regression analysis. Therefore, it is pointless to assess whether TDF or TPB showed a better model fit. However, in both the patient and the visitor sample, the TDF (53% and 60%) explained more variance in the self-reported hand hygiene behavior than the TPB (40% and 55%). Thus it can be concluded that both models are suitable for explaining hand hygiene behavior among hospital patients and visitors. Still, the more comprehensive TDF would be our model of choice to determine barriers and levers related to laypeople’s hand hygiene in healthcare facilities, and to use as a base for designing interventions.

Summary Goal Two: Identifying Critical Determinants

The second aim of the study was to find critical determinants of patients’ and visitors’ hand hygiene behavior. This was achieved by analyzing the correlations between the proposed factors and identifying the most relevant predictors for self-reported behavior. In both samples, all the pre-intentional TPB-variables attitude, subjective norm, and PBC significantly correlated with laypeople’s intention to sanitize their hands. The data showed that especially PBC, which are beliefs about the ease or difficulty of performing the behavior, play an essential role. For laypeople, the associations between both intention as well as PBC and hand hygiene behavior were significant. However, in the patient sample, the indirect effect between PBC and behavior was stronger than the direct effect, while the opposite was true for visitors. This implies that intention formation is more important for patients than visitors. For visitors, the ease or difficulty of hand hygiene (e.g., access to dispensers) was the most relevant direct predictor for the behavior. But for patients, who have more indications to sanitize their hands throughout the day, the ease or difficulty of cleaning one's hands might lead to the formation of a prognostic intention, whether it is worth bothering to engage in the behavior. All results are briefly summarized in Table 7.

Table 7
Support for the association between individual determinants and hand hygiene behavior

		Target group		
Theory[1]	*Variable*	*Patients*[1]	*Visitors*[1]	*Healthcare workers*[2]
TPB (40%, 55%)	Attitude	*	**	5/8[30–32, 35, 36]
	Subjective norm	**	**	7/8[29–34, 36]
	PBC	**	**	8/8[29–36]
	Intention	**	**	2/2[29, 36]
HAPA (44%, 37%)	Self-Efficacy	**	*	1/1[43]
	Outcome expectancies	*	*	*Not tested*
	Risk perception	*	*	*Not tested*
	Intention	**	**	*Not tested*
	Resources and barriers	*	ns	1/1[43]
	Action and coping planning	ns	ns	0/1
	Action control	**	**	1/1[43]
TDF (53%, 60%)	Knowledge and skills	ns	*	2/2[44, 46]
	Social/professional role and identity	**	**	1/2[46]
	Beliefs about capability	ns	ns	0/2
	Beliefs about consequences	ns	ns	1/2[46]
	Motivation and goals	*	ns	0/2
	Memory, attention, decision processes	**	**	2/2[44, 46]
	Environmental context and resources	ns	ns	2/2[44, 46]
	Social influences (norms)	ns	ns	0/2
	Emotions	**	*	0/2
	Behavioral regulations	ns	ns	0/2

Note. [1]results from the present study; (%) are the explained variances in self-reported behavior for patients and visitors in that order; ns = not significant, * $p < .05$, ** $p < .001$ with a link either directly to behavior or intention;

[2]results from previously published work; number of studies that found support for a variable out of total number reviewed (e.g., 5/8 five out of eight studies), with citation of the studies that found support in superscript

The correlations varied more between the two samples for the HAPA. For patients, self-efficacy, positive outcome expectations, perceived severity of harm, environmental resources, and action control were all significantly correlated with intention. From these factors, self-efficacy (i.e., beliefs in their capacity to execute the behavior) and action control (i.e., self-regulatory effort, self-monitoring, and awareness of standards) had the most substantial effects. Negative outcome expectations and perceived likelihood of experiencing a negative outcome did not considerably influence intention. Hand hygiene behavior correlated positively with intention and action control. These findings are overall in line with previous research that also found self-efficacy and outcome expectancies to be connected with handwashing intention, but risk perception or environmental barriers and resources were not included in their model (39). Similar to our findings, this study also reported intention and especially action control to be associated with hand hygiene behavior (39). However, in their longitudinal approach, action and coping planning were also indirectly associated with handwashing (39), which we did not find. Therefore, using a longitudinal method could alter the model fit in the present study.

Among visitors, also self-control, positive outcome expectations, and action control significantly correlated with the intention to clean their hands before and after patient contact. Other than the patients, the perceived likelihood of an adverse outcome but not the perceived severity was associated with intention. Negative outcome expectations and environmental resources did not influence intention. The only significant correlates for hand hygiene behavior among visitors was intention with an effect size similar to the patients' TPB data. This result is slightly at odds with the visitors' TPB data, where the association between intention and behavior was not as profound. Surprisingly, while action control correlated strongly with intention, it did not do so with self-reported behavior.

The correlations were more consistent between the two samples for the TDF model. For patients, role and identity, motivation and goals, memory, attention, and decision processes as well as emotions significantly correlated with hand hygiene behavior. For visitors, the significant predictors were role and identity, memory, attention, and decision processes, and knowledge and skills, as well as emotions. So the only difference was that instead of motivation and goals, knowledge and skills were associated with behavior, but both variables were only weak predictors. In both samples, role and identity, which are a person's self-standards and norms regarding their behavior and displayed personal characteristics in a social or work setting, were most strongly associated with the behavior. Memory, attention, and decision processes, which combined forgetting, a lack of focus, or prioritizing other tasks, was the second robust correlate to hand hygiene behavior among laypeople. Comparing the present study's results with findings from qualitative data (16), we can see memory, attention, and decision processes are a critical factor for patients' hand hygiene in both studies. In this other study, social influences were identified as an essential factor while we found role and identity to be a relevant predictor. The two domains are linked since both have social norms as an underlying process. More theoretical clarity about the distinction between the two domains might be needed. Finally, in our sample, knowledge and skills were only significantly associated with visitors' hand hygiene behavior and environmental context not relevant in either group. The healthcare systems or hospitals in which the data was collected might have played a role (Canada vs. Germany). While a lack of products/not recognizing hand rub as such was identified as a problem in the Canadian data, it did not show in our survey. All hospitals in our study had information material for patients and visitors regarding hand hygiene. This could explain why a lack of knowledge did not show as one of the most relevant barriers in our data, but we do not know what the situation was in the Canadian hospitals.

Looking only at the strongest and most coherent variables affecting self-reported hand hygiene behavior directly or indirectly, they can be assigned to two broad clusters. The first cluster includes PBC, action control, and memory, attention, and decision processes. Self-regulatory processes are at the core of all three constructs. Behavior change interventions to improve laypeople's hand hygiene behavior in healthcare facilities could use this insight. To reduce the need for self-regulation, hospitals could change the environment to nudge people to clean their hands when necessary. For instance, placing dispensers at highly visible and easily accessible locations (14, 54–56) and installing reminders (12, 57–60). Another option would be to implement more control and monitoring tools (e.g., personnel making sure that patients clean their hands before eating (61)). However, if that requires human labor, it might not be feasible for most facilities. Finally, interventions could be designed to improve self-regulation, which has shown promising in previous research (62).

The second cluster includes the factors subjective norm and role and identity. Social influence processes, especially norms, are at the heart of both constructs. Laypeople report cleaning their hands more often if they feel it is their responsibility to play an active role in preventing infections, and that other people expect them to do it. Therefore, interventions should be designed to convey this idea. Information material, signs, and other reminders should include normative messages to highlight laypeople's role within the facility's infection prevention strategy (12, 57, 60).

Summary Goal Three: Comparing Laypeople And Healthcare Professionals

The third and final aim of the present study was to examine whether essential determinants for hand hygiene behavior in hospitals differ between laypeople and healthcare professionals. This was achieved by comparing the results from our data with previous research on hand hygiene among healthcare workers using the same theoretical models. An overview of this comparison can be found in Table 7.

The TPB is the most widely used theory to identify determinants for hand hygiene behavior in the literature. Our results correspond with several papers that reported attitude, subjective norm, and PBC to be relevant predictors for self-reported hand hygiene compliance among hospital staff (30–32). Several other surveys found only two, but not all three pre-intentional variables to be important for self-reported behavior (29, 33–35). All studies that used the TPB to predict self-reported hand hygiene behavior identified PBC as being critical. When looking at observed hand hygiene behavior as an objective measure, PBC was also recognized as a significant predictor

(30, 36). Again, these findings correspond well with the present study's results, where PBC also emerged as the most influential factor for laypeople's hand hygiene behavior within the TPB.

To our knowledge, the only other research project that applied the HAPA to investigate hand hygiene behavior in the hospitals was the PSYGIENE project (43). In their cross-sectional survey, they found that self-reported hand hygiene compliance among physicians was associated with environmental resources, maintenance self-efficacy, and action control. Self-reported behavior among nurses was only linked to action control. The paper did not include the pre-intentional HAPA variables (risk-perception, outcome expectancies, and task self-efficacy) in the regression model. Unfortunately, a second study out of the project, which looked at the pre-intentional variables, did not report correlations with self-reported hand hygiene behavior (42). Combined with the published PSYGIENE data, we can see action control to be the only factor that is consistently associated with hand hygiene behavior (or intention) across all target groups. And this result is in line with other research (39) that also identified action control as the primary determinant for hand hygiene behavior among laypeople outside the healthcare context.

Two previous studies identified barriers and facilitators to hand hygiene behavior among healthcare workers, according to TDF (44, 46). Like these two studies, we also found memory, attention, and decision processes (i.e., forgetting, lack of focus, or prioritizing other tasks) to be among the most crucial barriers to adequate hand hygiene in hospitals. A second important factor for adequate hand hygiene behavior among healthcare workers was knowledge or lack of it (44, 46). However, knowledge correlated with self-reported hand hygiene behavior significantly only in our visitor sample, and the effect was not very profound. It certainly did not emerge as one of the most influential determinants among laypeople. In one of the healthcare worker studies (44), the method itself of asking people only when they made a mistake seemed to unveil to them that they did not know appropriate behavior according to the guidelines in this situation. In the other study, knowledge also was among the less influential determinants (46). Future research should include an objective measure of knowledge amongst laypeople to gain a better insight into how important the domain really is. The third consistent barrier to hand hygiene among healthcare workers in the two studies was environmental context and resources (mainly lack of time and accessibility of products), which we did not find relevant for laypeople's hand hygiene. This is plausible since patients and visitors are most likely not constrained by time pressure. Additionally, the availability of hand hygiene products was good in all hospitals in our study. Similar to our results, the domain professional/social role and identity was identified as an essential facilitator for hand hygiene practice in one (46) of the two previous studies. In the other study (44), scholars coded responses from healthcare professionals after non-compliance with guidelines was observed. It is plausible that healthcare workers do not link individual cases of non-compliance with their general professional identity at the moment of the event. The method with which determinants for people's hand hygiene behavior are investigated might itself strongly influence which determinants will surface as being important. Therefore, the responses laypeople give for cleaning or not cleaning their hands in an open-answer format should be compared to the results from the questionnaire findings.

Overall, the determinants of hand hygiene behavior for hospital patients and visitors are rather similar to healthcare workers'. Therefore, intervention strategies that have proven to be successful for hospital employees might also be useful for targeting laypeople.

Limitations

The present study had some limitations. First, all data, including the dependent variable, were self-reported. Previous research has shown that self-reported hand hygiene often only correlates weakly with actually observable behavior and is usually overrated (e.g., 29, 63). To our knowledge, within the hospital environment, the gap between self-reported and observable behavior has been demonstrated only for healthcare workers. Healthcare workers might be especially prone to overreport their compliance, since it is unquestionably an element of their professional duties. Also, employees might be deterred from openly disclosing non-compliance out of fear of reprimands since deviation from the guidelines poses a significant and potentially actionable threat to patient safety. It is unclear if laypeople are prone to overreport their hand hygiene behavior in hospitals to a similar degree. But handwashing rates after using the restroom outside hospitals showed that actual rates are significantly lower than self-reported rates (e.g., 64). However, in the hospital environment, self-reporting is the only feasible and economical way to gather data. Observing a comparably large sample of both patients and visitors in hospitals would be extremely labor-intensive, ethically questionable for its intrusive nature, and very disruptive for the workflow on the wards. Keeping the limitations of self-reported behavioral data in mind, there was no reasonable alternative in this case. Second, we employed a cross-sectional study design. This means that no statements about causal effects can be made. One drawback of path diagrams is that they imply a causal direction, which cannot be verified with a cross-sectional dataset. All associations between the self-reported hand hygiene behavior and model variables are bivariate correlations. But there is longitudinal research on both the TPB and HAPA, indicating the reliableness of the described path directions (53, 62, 65, 66). Third, while the internal consistency of most scales ranged between excellent and acceptable, some scales did not meet that goal. For the four scales ($HAPA_{Visitors}$: risk perception likelihood; $TDF_{Patients}$: beliefs about capabilities; $TDF_{Visitors}$: motivation and goals; and $TDF_{Visitors}$: environmental context) that did not meet a Cronbach's alpha of at least .60, single items representing the concept the best were included in the model. Measuring perceived risk likelihood with a single item is consistent with some other published research (42, 67). However, the two other more complex behavioral domains are probably not captured in its entirety with only one item. The bivariate correlation for beliefs about capabilities and environmental context did not differ strongly between patients and visitors. Therefore, the results would have probably not fundamentally changed, even when the scale had better psychometric qualities. However, for patients, the domain motivation and goal was one of the strongest predictors for self-reported behavior. We cannot disregard the possibility that if the visitor scale had better psychometric qualities, it would have also emerged as a strong predictor among this target group. Further research should be conducted to improve the quality of some of the TDF scales for non-healthcare professionals as target groups. Finally, even though we collected data in four different hospitals ranging from a small countryside clinic to a large university hospital, all of them were located in Germany and within a 100 km radius of each other. Therefore, we cannot tell if the conclusions drawn from our data could be generalized for other countries and especially for different cultures.

Conclusion

In conclusion, the present study is the first to systematically compare three theoretical models, TPB, HAPA, and TDF, on their usefulness for explaining hospital patients' and visitors' hand hygiene behavior. TDF accounted for the largest share of variance in laypeople's self-reported conduct. Two clusters of variables have emerged as important determinants for patients' and visitors' hand hygiene behavior: self-regulatory processes and social influence processes. Overall, the determinants for hand hygiene behavior are similar for laypeople and healthcare professionals. Therefore, patients and visitors can be included in the infection prevention strategy without substantial changes to the action plans. The results of the present study should help hospital hygiene practitioners to design and evaluate future interventions to improve patients' and visitors' hand hygiene behavior in healthcare facilities. Better hand hygiene practice among laypeople should help to reduce the rates of healthcare-associated infections and improve patient safety.

Abbreviations

TPB
Theory of Planned Behavior
HAPA
Health Action Process Approach
TDF
Theoretical Domains Framework
SEM
Structural Equation Modeling
WHO
World Health Organization
MRSA
Methicillin-Resistant Staphylococcus Aureus
PBC
Perceived Behavior Control
CFA
Confirmatory Factor Analysis
PSYGIENE
PSYchologically optimized hand hyGIENE promotion
MLF
Maximum Likelihood Estimation
FIML
Information Maximum Likelihood
RMSEA
Root Mean Square Error of Approximation
SRMR

Standardized Root Mean Square Residual
CFI
Comparative Fit Index
TLI
Tucker Lewis Index
AIC
Akaike Information Criterion
BIC
Bayesian Information Criterion

Declarations

Supplementary information

Additional file 1: Supplementary Table 1. Overview of key measures and psychometricdata of the three questionnaires for both visitors and patients.

Ethics approval and consent to participate

The University of Regensburg's Research Ethics Committeewaived the requirement for a full ethical review of the studybecause no personally identifiable data were collected.The study was approved by the executive clinic management of each of the four hospitals in which the survey was conducted.Participation in the survey was completely voluntary, and all participants gave consent to participate.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analyzed during the current study are available in the Open Science Frameworkrepository,https://osf.io/m2v56/.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

All authors (SG, PF, EL) developed the study concept and contributed to the study design. SG and EL developed the materials. SG organized and coordinated the data collection. SG analyzed and interpreted the data. SG drafted the article, and EL provided critical revisions. All authors (SG, PF, EL) have read and approved the manuscript.

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Figures

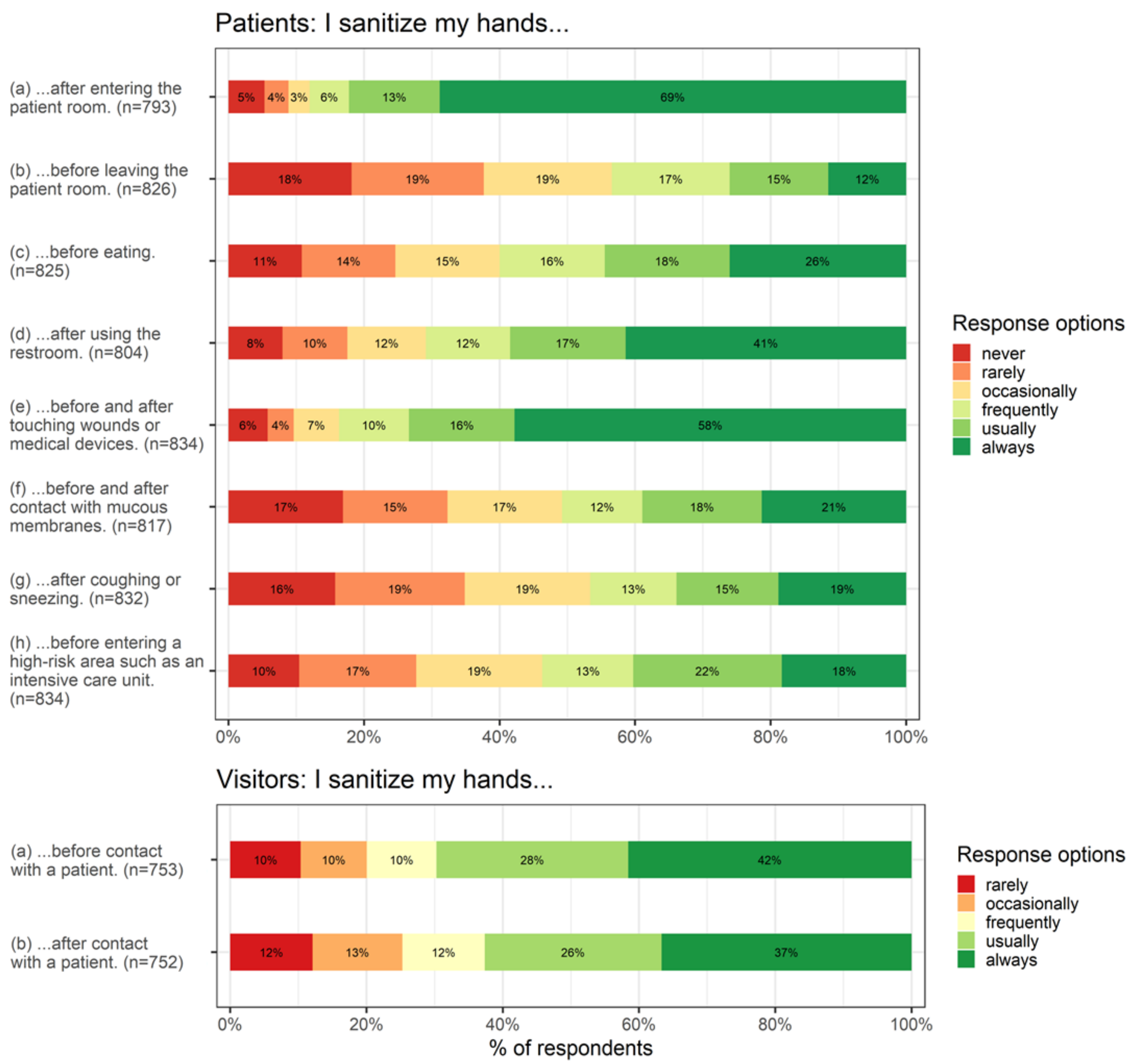

Figure 1

Frequency distributionof self-reported hand hygiene behavior in hospitals.

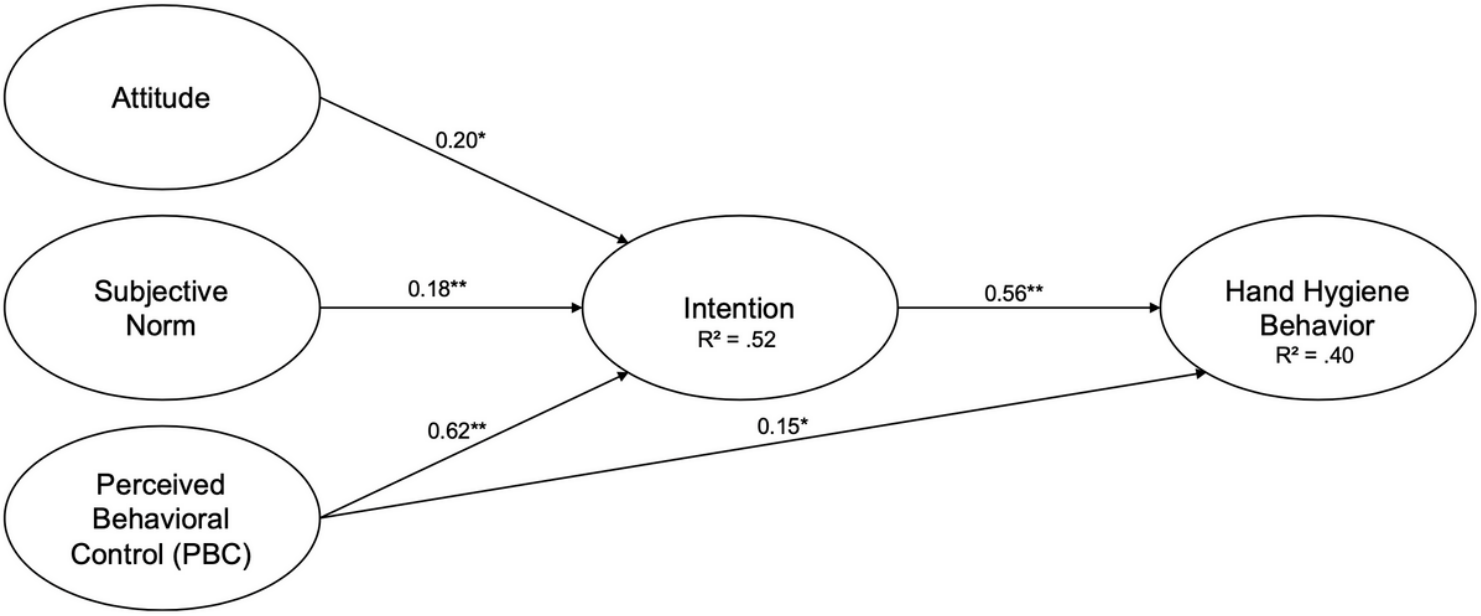

Figure 2

TPB path model with standardized parameter estimates to predict hospital patients’ hand hygiene behavior (Note: * p< .05, ** p< .001), n(total) =n(used) = 286.

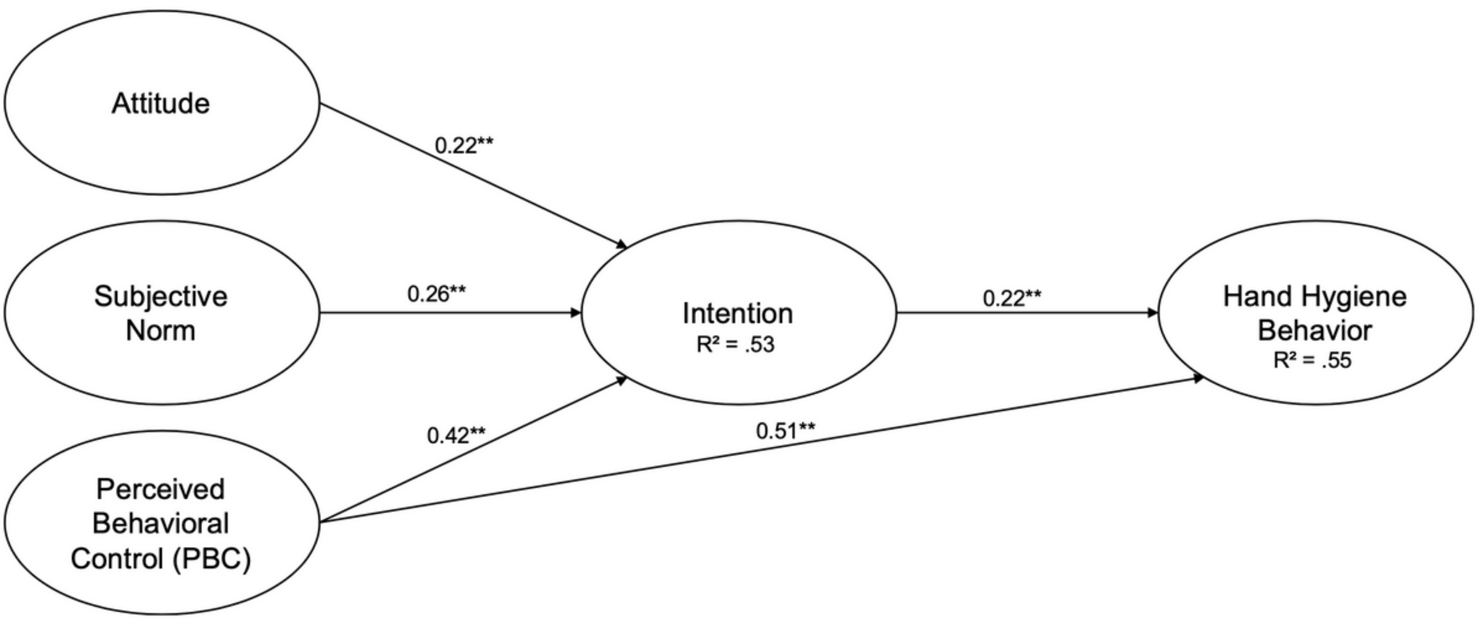

Figure 3

TPB path model with standardized parameter estimates to predict hospital visitors’ hand hygiene behavior (Note: * p< .05, ** p< .001), n(total) = 251, n(used) = 248.

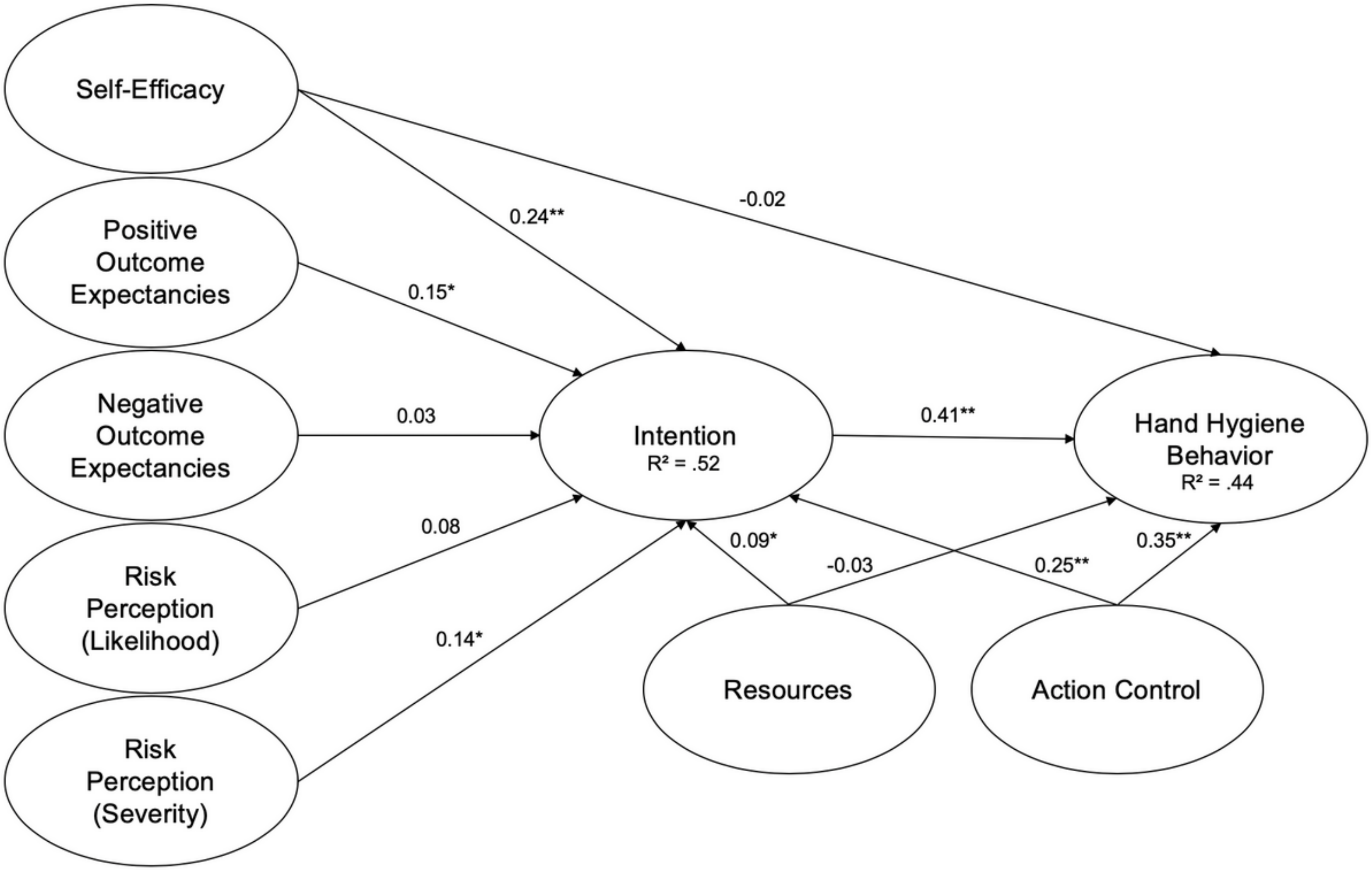

Figure 4

Adjusted HAPA path model with standardized parameter estimates to predict hospital patients' hand hygiene behavior (Note: * p< .05, ** p< .001), n(total) = 266, n(used)= 255.

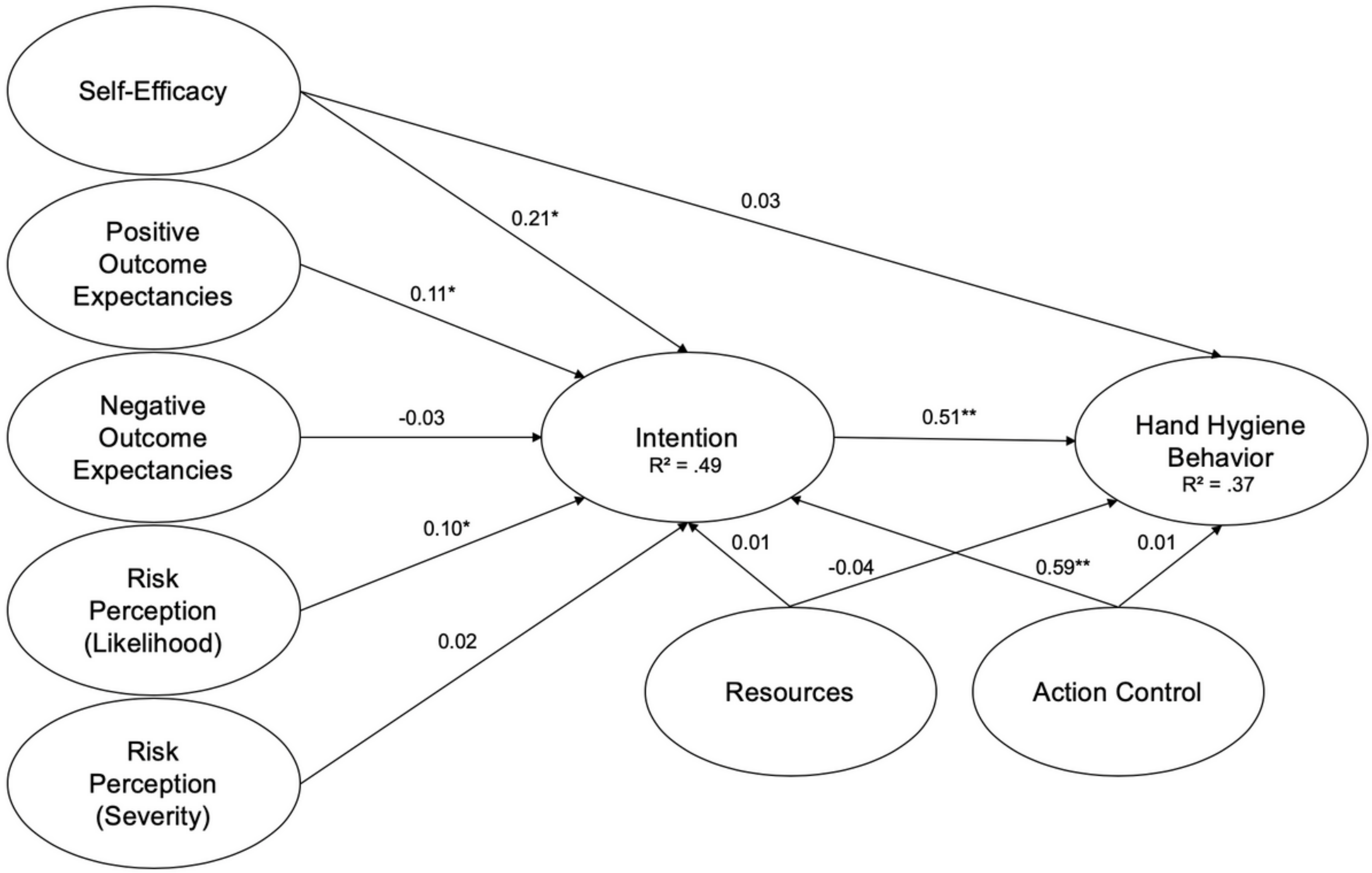

Figure 5

Adjusted HAPA path model with standardized parameter estimates to predict hospital visitors' hand hygiene behavior (Note: * $p < .05$, ** $p < .001$), n(total) = 264, n(used) = 257.

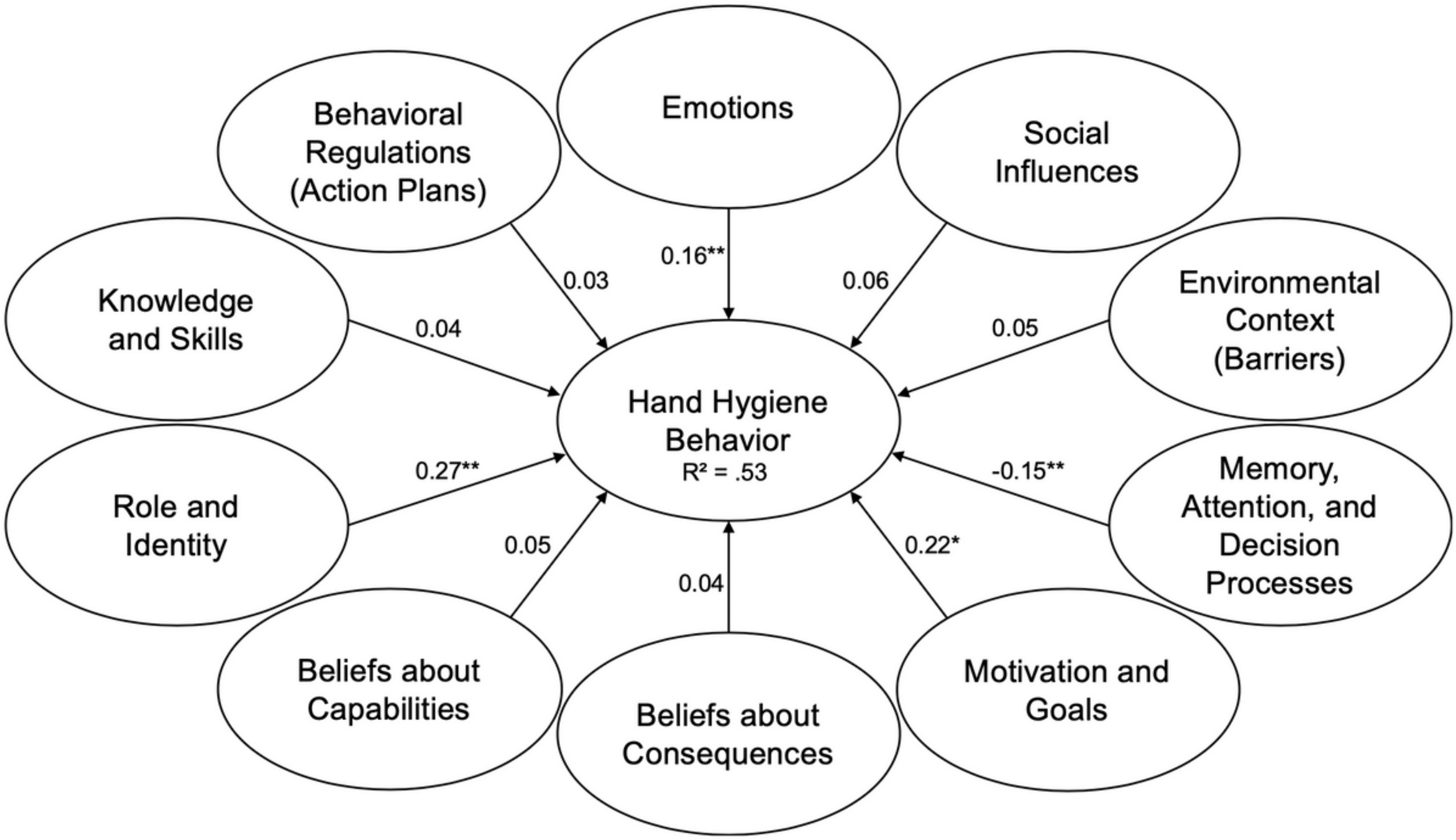

Figure 6

TDF path model with standardized parameter estimates to predict hospital patients' hand hygiene behavior (Note: * p< .05, ** p< .001), n(total) = 293, n(used) = 273.

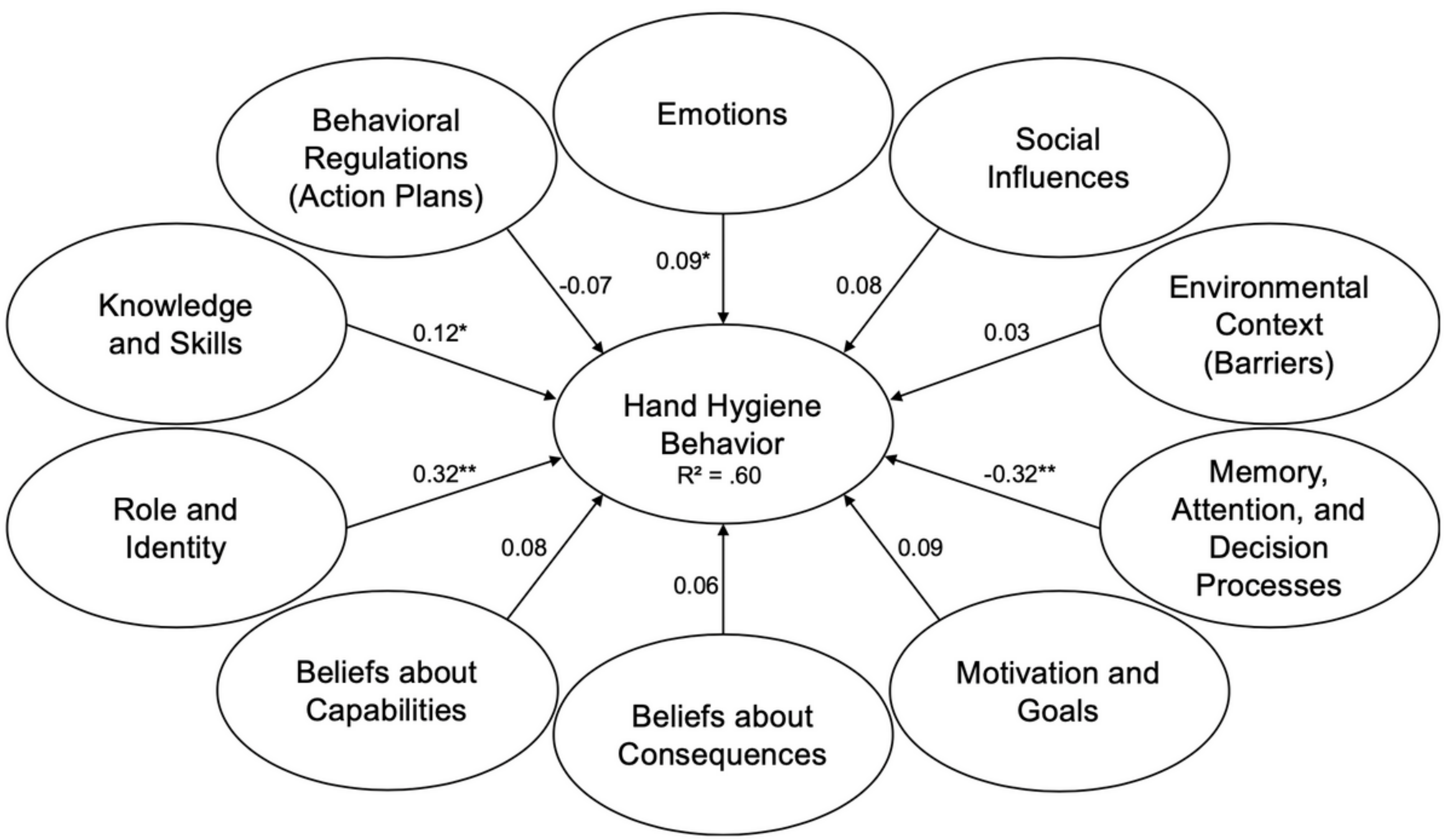

Figure 7

TDF path model with standardized parameter estimates to predict hospital visitors' hand hygiene behavior (Note: * $p < .05$, ** $p < .001$), n(total) =245, n(used) =238.

Supplementary Files

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