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Austrian Institute for
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Nudging interventions to optimise physician prescribing behaviour

Systematic Review

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Content

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List of abbreviations

aOR .....adjusted odds ratio
CDST .....Clinical decision support tools
CI.....Confidence interval
EHR .....Electronic health records
ELGA .....elektronische Gesundheitsakte (engl. electronic health record)
HIR.....Health insurance representative
IRR.....Incidence rate ratio
MD .....Mean difference
n.....Number of studies
NHS.....National Health Service
ÖGK .....Österreichische Gesundheitskasse (engl. Austrian health insurance fund)
OR .....Odds ratio
p.....p-value
RR .....Relative rate
RoB.....Risk of Bias
RQ .....Research question
TDF.....Theoretical Domains Framework
RCT.....Randomised controlled trial
SD.....Standard deviation
UK.....United Kingdom
USA .....United States of America

Executive Summary

Background and project aim

Despite evidence-based guidelines, suboptimal prescribing leads to severe consequences, including antimicrobial resistance, adverse patient outcomes, and substantial healthcare costs. Nudging interventions, subtle modifications to choice architecture that influence behaviour without restricting freedom, have emerged as promising strategies to optimise prescribing. This report systematically identifies nudging strategies implemented internationally for optimising prescribing behaviour, evaluates their effectiveness and safety, and analyses their suitability for implementation within the Austrian healthcare system.

systematic review evaluating nudging interventions for prescription optimisation with Austrian implementation feasibility

Methods

Building on an initial Medline search for systematic reviews, we performed an updated systematic search for randomised controlled trials across four databases (Medline, Cochrane, Embase, INAHTA) on 7-8 June 2025, complemented by reference list screening, leading to 1,447 primary studies after deduplication. Three categorisation systems, identified through hand search, were employed to systematically classify the identified nudges: the nudge intervention ladder (categorising by intensity level), the Theoretical Domains Framework (TDF, categorising by behavioural change factors), and the MINDSPACE framework (categorising by behavioural drivers). Implementation feasibility was assessed through expert consultation with three Austrian social insurance representatives via an online questionnaire.

systematic search: 1,447 hits

4 databases

nudging categorisation

expert questionnaire

Results

Identified nudges and categorisation (RQ1)

Eleven RCTs examined 22 nudges across antibiotics, opioids, and other medications (five and three studies each, respectively), with heterogeneous study scales (44 to > 5,000 practices, 12-24 months). Main approaches: peer comparison (e.g., via email-based rankings with colleagues), clinical decision support systems (CDSS), mandatory justification (written justification of prescription decisions), and educational visits (structured visits by health insurance representatives). The risk of bias (RoB) for the study outcomes ranged from low to high, with most receiving a "some concerns" rating due to awareness bias and the selection of the reported data.

11 RCTs with 22 nudges, 3 drug categories: antibiotics (n=5), opioids (n=3) and other medications (n=3)

most common approach: peer comparison

Interventions were distributed across three intensity levels: eleven low-intensity (e.g. peer comparison, letters, newsletters), seven mid-intensity (e.g. electronic alerts), and four high-intensity [e.g. clinical decision support tools (CDST), multicomponent interventions]. Behavioural analysis revealed emotion (18 nudges), social influences (17), and behavioural regulation (16) as dominant TDF domains, while MINDSPACE categorisation showed ego and affect (19) as primary drivers, followed by messenger effects (15) and priming (eleven).

11 low-, 7 medium-, 4 high-intensity nudges

emotional and social behavioural determinants predominate

Effectiveness and Safety (RQ2)

Effectiveness outcomes: Low-intensity interventions, e.g. peer comparison, consistently reduced prescribing across categories. Mid-intensity interventions showed mixed results, with accountable justification effective but other approaches non-significant. High-intensity interventions demonstrated variable effectiveness, with some achieving substantial reductions, e.g. CDSTs, while others showed no significant effects.

low-intensity: effective across all medication categories vs. CG; mid/high-intensity: variable effectiveness vs. CG

Safety outcomes: Limited data (four/eleven studies) showed that most interventions were non-inferior regarding hospitalisation rates. One mid-level intervention showed higher return visit rates for possible bacterial infections (1.41% versus 0.43%).

limited (n=4) but reassuring safety data

Economic outcomes: Sparse data (three studies) showed minimal differences in prescription costs between intervention and control groups. Implementation costs ranged from £210 per practice (high-level CDST) to £1,191 per practice (comprehensive educational programmes).

sparse economic data (n=3): no substantial cost savings demonstrated

Implementation Feasibility in Austria (RQ3)

Nudge implementation feasibility varies by intervention type. Educational interventions and mandatory justification are highly feasible via existing infrastructure. CDST face system integration barriers requiring a phased approach. Peer comparison shows mixed feasibility, with concerns about workload. Multicomponent interventions are least feasible due to their complexity and require pilot programs.

implementation feasibility varies by intervention type

Critical interpretation and limitations

Critical evidence gaps include insufficient safety data despite their impact on patient outcomes, minimal economic differences that challenge cost-saving assumptions, and limited transferability from UK/USA primary care settings to Austrian healthcare.

evidence gaps: missing safety and economic outcomes

The predominant engagement of ego and affect (each in 19 nudges) raises ethical concerns. These interventions achieve change through emotional engagement and concerns about professional reputation, rather than through enhanced clinical reasoning, and operate through social proof rather than rational deliberation. This raises fundamental questions about autonomy, consent, and paternalism: nudging subtly influences decisions without explicit awareness, potentially undermining informed, autonomous choice and leading to decisions clinicians might not have made. In contexts of economic austerity, nudging may be perceived as undermining professional autonomy for budgetary rather than clinical objectives.

ethical concerns: questions about professional autonomy, consent, and paternalism

Limitations of the data basis are due, on the one hand, to the risk of bias in the studies, which were mainly rated as having some concerns, and, on the other hand, to the fact that follow-up data after the intervention remain sparse (12-24 months follow-up), leading to uncertainty regarding the durability of the effects. Methodological limitations include strict inclusion criteria, manual search methods, and the involvement of only three representatives of the social insurance in the expert consultation, which limited its representativeness and did not consider the perspectives of healthcare professionals.

limitations

Conclusion

nudging may modify prescribing behaviour

Nudging interventions may modify prescribing behaviour, with lower-intensity interventions (remarkably, peer comparison) consistently outperforming high-intensity approaches despite requiring fewer resources.

successful implementation requires a phased approach, system integration, training and stakeholder engagement with continuous monitoring

Austrian implementation feasibility varies substantially: educational approaches and mandatory justification demonstrate the highest feasibility due to their alignment with existing infrastructure; CDST face technical integration barriers; and multicomponent interventions raise concerns about resource intensity. Essential implementation considerations include phased approaches, comprehensive system integration, training of healthcare personnel, ongoing monitoring, and incorporating physician perspectives for sustainable implementation.

Zusammenfassung

Hintergrund und Zielsetzung

Nudging als verhaltenswissenschaftliche Strategie zur Verschreibungsoptimierung

Trotz vorhandener Empfehlungen evidenzbasierter Leitlinien kann ein suboptimales Verschreibungsverhalten zu schwerwiegenden Folgen, darunter Antibiotikaresistenzen, unerwünschten Ereignissen bei Patient:innen und erheblichen Gesundheitskosten, führen. Nudging-Interventionen, definiert als subtile Modifikationen der Entscheidungsarchitektur, die das Verhalten beeinflussen, ohne die Wahlfreiheit einzuschränken, haben sich als mögliche Strategien zur Optimierung des Verschreibungsverhaltens von Ärzt:innen etabliert. Diese Ansätze unterscheiden sich grundlegend von traditionellen regulatorischen Maßnahmen, indem sie nicht auf Verbote oder finanzielle Anreize setzen, sondern die Entscheidungsumgebung so gestalten, dass erwünschte Verhaltensweisen wahrscheinlicher werden.

in Ö Nudging-Potenzial wenig genutzt; SR mit 3 Forschungsfragen (FF): FF1: Identifikation und Kategorisierung international implementierter Nudges, FF2: Effektivität und Sicherheit, FF3: Implementierbarkeit in Ö

Im österreichischen Gesundheitswesen wird das Potenzial von Nudging-Interventionen bislang wenig genutzt. Zwar existieren einzelne Initiativen wie die Widerspruchslösung bei der Organspende oder der elektronische Erstattungskodex (eEKO), doch fehlt es an einer systematischen und umfassenden Anwendung verhaltensökonomischer Strategien in weiteren Bereichen des Gesundheitssystems, in denen Nudging potenziell positive Wirkungen entfalten könnte – beispielsweise bei der Optimierung der Medikamentenverschreibung von Ärzt:innen. Vor diesem Hintergrund verfolgt dieser Bericht drei Zielsetzungen: die systematische Identifikation und Kategorisierung international implementierter Nudging-Strategien zur Optimierung des Verschreibungsverhaltens (Forschungsfrage [FF] 1), die Bewertung ihrer Wirksamkeit und Sicherheit (FF2) sowie die Analyse ihrer Eignung für das österreichische Gesundheitssystem (FF3).

Methodik

systematische Suche: 1.447 Treffer

4 Datenbanken

Aufbauend auf einer initialen Medline-Suche nach systematischen Reviews wurde am 7. Und 8. Juni 2025 eine aktualisierte systematische Suche nach randomisierten kontrollierten Studien in vier Datenbanken (Medline, Cochrane, Embase, INAHTA) durchgeführt, ergänzt durch Screening von Referenzlisten. Dies ergab eine Trefferzahl von 1.447 Primärstudien nach Deduplizierung.

Kategorisierung der Nudges

Expert:innenkonsultation zur Implementierbarkeit

Zur Kategorisierung der Nudges wurden mittels Handsuche drei Rahmenmodelle identifiziert: Die Nudge-Interventionsleiter (Nudge intervention ladder) diente zur Klassifikation nach Interventionsintensität (niedrig, mittel, hoch), der Theoretical domains framework (TDF) zur Identifikation relevanter Verhaltensänderungsfaktoren und er MINDSPACE Framework zur Analyse zugrunde liegender Verhaltensdeterminanten. Die Machbarkeitsanalyse für das österreichische Gesundheitssystem erfolgte durch Expert:innenkonsultation mit drei Vertreter:innen der Sozialversicherung mittels Online-Fragebogen.

Ergebnisse

Identifizierte Nudges und Kategorisierung (FF1)

11 RCTs mit 22 Nudges

3 Medikamenten-kategorien: Antibiotika (Anzahl der Studien, n=5), Opioide (n=3) und sonstige Medikamente (n=3)

häufigster Ansatz: Peer-Vergleich

Es wurden elf randomisierte kontrollierte Studien (RCTs) eingeschlossen, die insgesamt 22 Nudging-Interventionen untersuchten. Die Studien verteilten sich wie folgt: fünf Studien zu Antibiotika (mit elf Nudges), drei Studien zu Opioiden (mit sieben Nudges) und drei Studien zu anderen Medikamenten (mit vier Nudges). Die Studien umfassten 44 bis über 5.000 Praxen mit Patient:innenpopulationen von 3.900 bis über 330.000 Teilnehmer:innen und Interventionsdauern von zwölf bis 24 Monaten. Das Risiko für Verzerrung der Studienendpunkte reichte von niedrig bis hoch. Die meisten Studienergebnisse erhielten dabei die Bewertung „einige Bedenken" aufgrund von Verzerrungen durch Wissen über die Intervention und selektive Datenberichterstattung. Die häufigsten Nudges waren der **Peer-Vergleich** (Vergleich mit Fachkolleg:innen, z. B. per E-Mail verteilte Ranglisten, individualisierte Rückmeldungen, Leistungsvergleiche), **klinische Entscheidungsunterstützungssysteme** (CDST, Systeme, die elektronische Gesundheitsaufzeichnungen integrieren), **verpflichtende Begründung** (verpflichtende schriftliche Begründungen von Verschreibungsentscheidungen) und **Bildungsbesuche** (strukturierte Besuche von Krankenversicherungsvertreter:innen).

11 niedrig-, 7 mittel-, 4 hochintensive Interventionen

emotionale und soziale Verhaltensdeterminanten überwiegen

Die Kategorisierung nach Intensität ergab elf niedrigintensive Interventionen (z. B. Peer-Vergleich, standardisierte Briefe und Newsletter), sieben mittelintensive Interventionen (z. B. elektronische Hinweismeldungen) sowie vier hochintensive Interventionen (z. B. klinische Entscheidungsunterstützungssysteme und Interventionen mit mehreren Komponenten). Die Kategorisierung nach Verhaltensänderungsfaktoren zeigte, dass Emotionen (18 Nudges), soziale Einflüsse (17 Nudges) und Verhaltensregulationen (16 Nudges) die häufigsten Domänen waren. Die Kategorisierung nach Verhaltensdeterminanten ergab, dass Ego und Affekt (jeweils 19 Nudges) dominierten, gefolgt von Nachrichten-Effekten (15 Nudges) und „Priming" (elf Nudges).

Wirksamkeit und Sicherheit (FF2)

niedrigintensive Nudges (z. B. Peer-Vergleich) zeigen Wirksamkeit im Vergleich zu Kontrollgruppen (KG) bei allen Medikamentenkategorien

Wirksamkeit: Niedrigintensive Interventionen zeigten eine konsistente Wirksamkeit gegenüber Kontrollinterventionen in allen Medikamentenkategorien: Der Peer-Vergleich reduzierte im Vergleich zur Kontrollgruppe signifikant die Verschreibungen von Antibiotika und Opioid-Tabletten sowie Langzeitverschreibungen, gleichzeitige Opioid/Benzodiazepin-Verschreibungen und Neuverordnungen verschiedener Medikamente. Versendete Briefe mit Peer-Vergleich erreichten eine signifikante Reduktion der relativen Verschreibungsrate um 5 % gegenüber der Kontrolle. Edukative Newsletter mit einem Peer-Vergleich reduzierten hochriskante Verschreibungen von Antipsychotika, nichtsteroidalen Antirheumatika und Thrombozytenaggregationshemmern signifikant.

mittelintensive Nudges (z. B. verpflichtende Verschreibungs-begründung) …

Mittelintensive Interventionen zeigten eine variable Wirksamkeit: Bei Antibiotika zeigte die Verschreibungsbegründung (Accountable justification) eine signifikante Reduktion um 7 %, während vorgeschlagene Alternativen (Suggested alternatives) keine signifikanten Unterschiede zur Kontrollgruppe aufwiesen, jedoch insgesamt die Antibiotikaverschreibungen im Vergleich zu vor der Intervention signifikant reduzierten. Bei Opioiden zeigten mittelintensive Interventionen mit Leitlinien-Checklisten ebenfalls keine signifikanten Effekte im Vergleich zur Kontrolle.

… und hochintensive Nudges (z. B. klinische Entscheidungs-unterstützungssysteme, CDST) zeigen variable Wirksamkeit im Vergleich zu KG

Hochintensive Interventionen erzielten gemischte Ergebnisse: Signifikante Reduktionen im Vergleich zur Kontrolle wurden bei Antibiotika durch eine Multikomponenten-Intervention bei der Verschreibungsrate sowie durch ein klinisches Entscheidungsunterstützungssystem mit Feedback bei den verschriebenen Tagesdosen erreicht. Ein weiteres klinisches Entscheidungsunterstützungssystem zeigte im Vergleich zur Kontrolle keine signifikanten Veränderungen. Bei der Verschreibung sonstiger Medikamente reduzierten elektronische Entscheidungsunterstützungssysteme durch umfassende Medikationsreviews die Gesamtzahl der verschriebenen Medikamente signifikant.

limitierte (n=4), aber positive Sicherheitsdaten

Sicherheit: Die Sicherheitsdaten waren eingeschränkt, da nur vier Studien Ergebnisse zur Sicherheit der Interventionen berichteten. Die meisten Interventionen zeigten keine Unterschiede bei den Hospitalisierungsraten. Eine Kombinationsintervention (verpflichtende Verschreibungsbegründung plus Peer-Vergleich) zeigte bei möglichen bakteriellen Infektionen bei keiner initialen Antibiotikagabe eine höhere Wiedervorstellungsrate. Berichtete schwerwiegende unerwünschte Ereignisse standen nicht im Zusammenhang mit den Interventionen.

limitierte ökonomische Daten (n=3): fehlender Nachweis substanzieller Kosteneinsparungen

Die Datenlage zu ökonomischen Aspekten war begrenzt (drei Studien) und zeigte nur minimale Unterschiede bei den Verschreibungskosten zwischen der Interventions- und der Kontrollgruppe. Die Implementierungskosten lagen zwischen £ 210 (CDST) und £ 1.191 pro Praxis (umfassende Bildungsprogramme).

Implementierbarkeit in Österreich (FF3)

Implementierbarkeit variiert: Bildung und Verschreibungsbegründung gut implementierbar; CDST durch technische Herausforderungen limitiert; Multikomponenten-interventionen zu komplex

Die Expertenkonsultation ergab unterschiedliche Einschätzungen der Machbarkeit für verschiedene Interventionstypen. **Edukative Interventionen** zeigten die höchste Machbarkeit: Sie wurden als „praxistauglich" bewertet und lassen sich gut in bestehende Sozialversicherungskommunikationskanäle integrieren, wobei die Kapazitäten der Sozialversicherungen für umfassende Programme als limitierender Faktor identifiziert wurden. **Verpflichtende Verschreibungsbegründungen** wiesen aufgrund bestehender rechtlicher Rahmenbedingungen (Ärzteverordnungsgesetz), die bereits eine umfassende Dokumentation vorschreiben, eine hohe Machbarkeit auf. Die Implementierungsbarrieren waren minimal und die erwartete Akzeptanz hoch. **Klinische Entscheidungsunterstützungssysteme** zeigten eine moderate Machbarkeit. Obwohl ihr Potenzial anerkannt wurde, bestehen erhebliche technische Herausforderungen bei der Systemintegration sowie hohe Ressourcenanforderungen für die Entwicklung und Schulung. Der **Peer-Vergleich** ergab gemischte Machbarkeitsbewertungen: Zwar werden ähnliche Ansätze bereits bei der Österreichischen Gesundheitskasse angewandt, jedoch wurde der hohe Personal- und Zeitaufwand für die Umsetzung des Nudges kritisch gesehen. Betont wurde die Notwendigkeit einer konstruktiven statt punitiven Gestaltung. **Multikomponenten-Interventionen** zeigten die geringste Machbarkeit. Hauptbedenken gingen auf die Systemkomplexität, die Ressourcenintensität und das Risiko der Überforderung zeitkritisch arbeitender Gesundheitsdienstleister zurück.

Kritische Interpretation und Limitationen

kritische Evidenzlücken bei Sicherheit, Ökonomie und geografischer Generalisierbarkeit limitieren Übertragbarkeit

Mehrere Evidenzlücken erfordern besondere Aufmerksamkeit: die unzureichende Dokumentation von Sicherheitsaspekten ist vor dem Hintergrund, dass Nudging-Interventionen klinische Entscheidungsprozesse modifizieren und patient:innenrelevante Outcomes beeinflussen, als kritische Limitation zu werten. Die spärliche gesundheitsökonomische Evaluation zeigt minimale Unterschiede bei den Verschreibungskosten zwischen den Gruppen, was darauf hindeutet, dass Nudging möglicherweise nicht die erwarteten Kosteneinsparungen erzielt. Die geografische Konzentration auf britische und US-amerikanische Gesundheitssysteme schränkt die Generalisierbarkeit auf den österreichischen Versorgungskontext ein.

niedrigintensive teils effektiver als hochintensive Nudges

Die niedrigintensiven Interventionen zeigten teils bessere Ergebnisse als die hochintensiven Ansätze, was darauf hindeutet, dass Verhaltensmechanismen besser auf einfache, kontextuell eingebettete Nudges als auf komplexe technologische Lösungen reagieren.

Ego-/Affekt-Aktivierung wirft ethische Fragen zu Autonomie, Transparenz und budgetgetriebenem Paternalismus auf

Die vorherrschende Aktivierung von Ego und Affekt (jeweils in 19 Nudges) durch die Interventionen wirft ethische Bedenken auf. Diese Interventionen erzielen Verhaltensänderungen durch emotionale Ansprache und Bedenken hinsichtlich der beruflichen Reputation, statt die klinische Denkweise zu verbessern; sie wirken über soziale Einflüsse statt durch rationale Überlegungen. Dies wirft grundlegende Fragen zu Autonomie, Einwilligung und Paternalismus auf: Nudging beeinflusst Entscheidungen subtil, oft, ohne dass sich die Betroffenen dessen bewusst sind, was informierte, autonome Entscheidungsfindungen untergraben und zu Entscheidungen führen kann, die Ärzt:innen sonst nicht getroffen hätten. In Kontexten ökonomischer Austerität könnte Nudging als Untergrabung der professionellen Autonomie für budgetäre statt klinische Zielsetzungen wahrgenommen werden.

Limitationen: restriktive Einschlusskriterien, Langzeiteffekte, fehlende Ärzt:innen-Perspektive

Einschränkungen der Datenbasis ergeben sich einerseits aus dem überwiegend als bedenklich eingestuften Verzerrungsrisiko der Studien sowie aus der kurzen Nachbeobachtungsdauer (12-24 Monate), die Unsicherheiten hinsichtlich der Nachhaltigkeit der Effekte mit sich bringt. Andererseits bestehen methodische Limitationen durch strenge Einschlusskriterien, manuelle Suchmethoden und die begrenzte Repräsentativität der Expert:innenkonsultation, an der lediglich drei Vertreter:innen der Sozialversicherung teilnahmen, wodurch die Perspektive der Gesundheitsfachkräfte unberücksichtigt blieb.

Schlussfolgerung

Nudging modifiziert Verschreibungsverhalten; jedoch Evidenzlücken bei Sicherheit und Ökonomie

Die Evidenz deutet darauf hin, dass Nudging-Interventionen das Verschreibungsverhalten beeinflussen können. Niedrigintensive Interventionen (insbesondere Peer-Vergleichsmechanismen) übertreffen hochintensive Ansätze dabei konsistent, obwohl sie weniger Ressourcen erfordern. Die Evidenzbasis bleibt jedoch durch unzureichende Sicherheitsevaluationen, spärliche Daten zu ökonomischen Outcomes und die geografische Konzentration der Studien limitiert.

heterogene Implementierbarkeit nach Interventionstyp

Die Machbarkeit einer Implementierung im österreichischen Kontext variiert erheblich je nach Interventionstyp. Edukative Ansätze und verpflichtende Begründung wurden aufgrund ihrer Vereinbarkeit mit der bestehenden Infrastruktur und den rechtlichen Rahmenbedingungen als besonders gut umsetzbar eingeschätzt. Klinische Entscheidungsunterstützungssysteme gehen bei ELGA- und E-Medikation-Plattformen mit technischen Integrationsbarrieren einher. Bei Multikomponenten-Interventionen bestehen Bedenken hinsichtlich der Ressourcenintensität und der Komplexität.

Anforderungen für erfolgreiche Implementierung

Für die weitere Implementierung von Nudges in Österreich sind mehrere Aspekte zentral: ein phasenweiser Ansatz beginnend mit gut umsetzbaren Interventionen, systematische Integration unter Beachtung technischer und datenschutzrechtlicher Anforderungen, Schulungen für Gesundheitspersonal, kontinuierliches Monitoring der Effekte sowie die Einbeziehung ärztlicher Perspektiven.

1 Introduction

1.1 Nudge interventions

globale Krisen erfordern neue Verhaltensänderungs-strategien;

Nudging als Alternative

Over the last few years, society has faced numerous pressing challenges, from navigating global health crises such as COVID-19 and antimicrobial resistance [1] to mitigating climate change, which requires substantial shifts in individual behaviour [2]. Traditional approaches to behaviour change have predominantly relied on microeconomic and psychological models premised on rational decision-making. However, over the past decade, a new type of behavioural change intervention, commonly referred to as 'nudge', has garnered considerable attention from researchers and policymakers as a complementary strategy [2].

Nudges: subtile Modifikationen der Entscheidungsarchitektur

Nudges are behavioural change techniques that use psychological insights to guide individuals toward choices they would consider beneficial themselves. The term "behavioural change technique" reflects this approach's foundation in psychological research and its objective of achieving population-level behavioural modifications through informed choice architecture [3]. Choice architecture deliberately structures decision-making environments, subtly shaping how options are presented to influence choices, often below conscious awareness [4]. By applying insights from research on human motivation, cognition, and decision-making, policymakers can design contexts that make preferred options more accessible and intuitive to select [3].

Nudges ändern Verhalten vorhersehbar ohne Optionen zu verbieten oder ökonomische Anreize zu verändern

Nudges represent subtle alterations to decision frameworks or information presentation grounded in behavioural science insights that influence behaviour without limiting freedom of choice [2, 5]. In the words of Richard Thaler and Cass Sunstein, authors of the book "Nudge – Improving Decisions about Health, Wealth, and Happiness" [6]: *"A nudge, as we will use the term, is any aspect of the choice architecture that alters people's behavior predictably without forbidding any options or significantly changing their economic incentives. To count as a mere nudge, the intervention must be easy and cheap to avoid. Nudges are not mandates. Putting fruit at eye level counts as a nudge. Banning junk food does not."*

einfache und kostengünstige Umsetzung

As nudge interventions are typically straightforward and inexpensive, they are very popular with health managers and policymakers [7]. They span a wide range, and their number and variety are constantly growing. Table 1-1 presents the six choice architecture categories initially suggested by Thaler and Sunstein, along with brief descriptions [8].

Table 1-1: Categories of choice architecture and their definition [8]

Category of Choice Architecture	Definition and Example of Nudges within the Choice Architecture Category
Setting default choices	Structuring the choice set such that the desired choice(s) is the one that follows "the path of least resistance." Example: Changing the default setting in medication ordering software to a smaller dose.
Error reduction	Anticipating errors that are likely to occur due to human error and designing systems to account for these through prompts or forced stops. Example: Designing medication delivery systems to fit only the intended medication.

Category of Choice Architecture	Definition and Example of Nudges within the Choice Architecture Category
Providing feedback	Informing decision-makers of their performance or the consequences of their choices gives them the opportunity to align their behaviour with the desired outcomes. Example: Informing people of their performance relative to a set benchmark or peer average.
Understanding mappings	Helping decision makers understand the pathways and mechanistic relations between choices and outcomes when those pathways or mechanisms are complex. Example: Presenting information in ways that are meaningful to the decision maker.
Structuring complex choices	Creating meaningful partitioning of the choice set or creating sorting mechanisms according to preferences or needs. Example: Presenting options based on previous choices or peer choices.
Increasing salience of information or incentives	Making information or incentives more noticeable and attractive. Example: Highlighting text or displaying information in a novel manner.

sektorübergreifende Evidenz zeigt Wirksamkeit

Evidence from diverse sectors, including financial markets, educational policy, and healthcare, demonstrates that these behavioural interventions can effectively influence decision-making patterns through environmental design rather than through mandates or incentives [9].

1.2 Nudges in health care

erfolgreiche Anwendung von Nudging in Gesundheitspolitik: z. B. reduzierter Tabakkonsum durch visuelle Warnungen

Government policy sectors have embraced nudging interventions with considerable success, particularly in public health initiatives. A prominent application involves default settings, exemplified by automatic enrolment in organ donation programmes, which substantially increases potential donor numbers by leveraging individuals' tendency towards status quo bias [10], i.e. the tendency to prefer that things stay the same or to avoid changing pre-selected options. Increasing the salience of information or incentives, e.g., visual nudges [11], represents another effective category: graphic health warnings on tobacco packaging have demonstrated measurable reductions in smoking behaviour through emotional salience [12].

breites Anwendungsspektrum: Prävention, Versorgung und professionelle Leitlinienadhärenz

The scope for nudging applications in healthcare extends across diverse policy domains, encompassing preventive care initiatives, healthcare service delivery, long-term care strategies, community-based networks, and digital health innovations. Whilst research has traditionally concentrated on patient-directed interventions, including vaccination reminders, diagnostic testing protocols, and chronic disease self-management, healthcare professional-targeted nudges have emerged as equally promising approaches for enhancing guideline adherence and prescribing quality [8, 9, 13].

1.2.1 Choosing the right nudge

Entwicklung und Implementierung von Nudges durch Rahmenbedingungen und systematische Ansätze

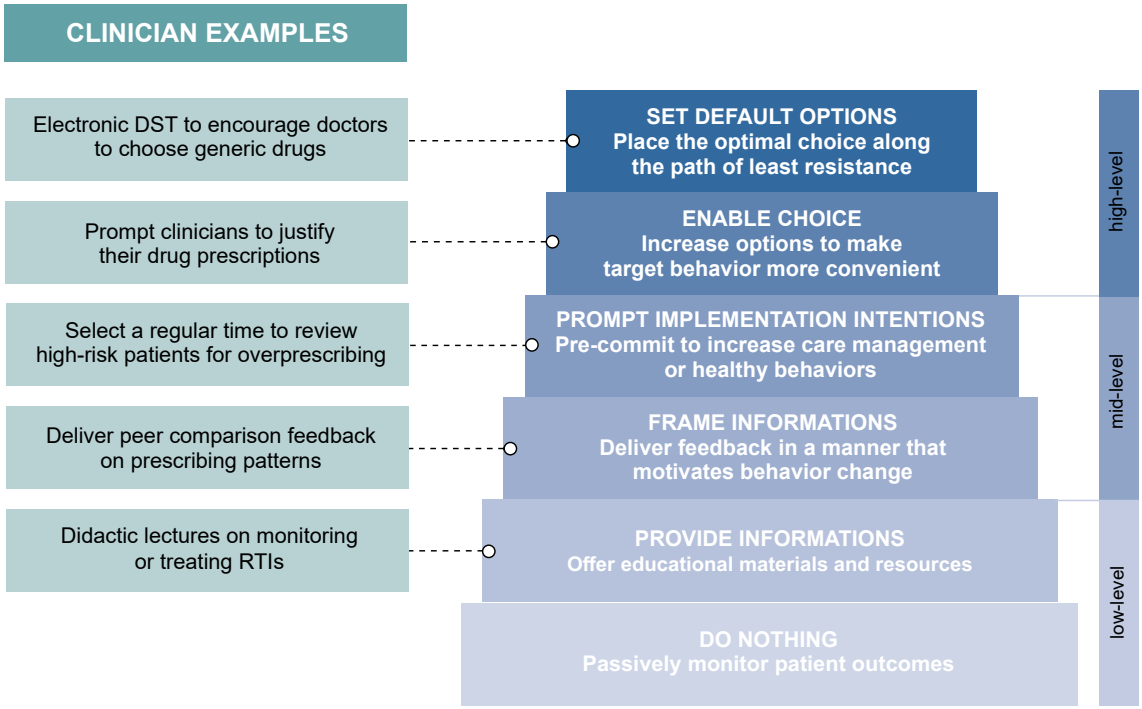
Nudges employ diverse approaches and yield varying levels of effectiveness [14]. Strategic development and implementation of nudging interventions can substantially enhance healthcare delivery through optimal design, seamless workflow integration, comprehensive stakeholder engagement, and rigorous experimentation [5]. To support the steps of development and implementation, various researchers and research groups have developed approaches and

ideas, such as the nudge intervention ladder [14] or various frameworks [15-19]. In the following section, some approaches particularly in demand in the healthcare sector are briefly described.

Nudge Intervention Ladder

Nudge-Interventionsleiter mit 3 Intensitätsstufen: niedrig, mittel, hoch (steigende Ressourcenintensität)

Health systems can use the Nuffield Council on Bioethics intervention ladder [20] to help guide the development and implementation of nudges in clinical settings [14]. The Nudge Intervention Ladder distinguishes three levels of intervention intensity: low, mid, and high. Moving up the ladder (see Figure 1-1) represents a progression from passive, low-resource interventions to more active, resource-intensive strategies, which can drive greater behavioural change. While low-level nudges require minimal upfront investment, high-level interventions demand more planning, development, and implementation costs but typically yield stronger results in modifying healthcare behaviours and decision-making patterns [5].



Abbreviations: RTIs – Respiratory tract infections; DST – Decision support tool

Figure 1-1: Nudge ladder adapted from Harrison et. al and Waddel et. al

unterstützt die Einschätzung des Implementierungsaufwands und der erwarteten Wirkung

The ladder helps organisations evaluate the trade-offs between implementation effort and expected impact when designing nudges in healthcare settings. It thus provides a structured way to consider which level of nudging aligns with available resources and desired outcomes [5]. Examples across the three levels of nudge interventions include:

niedrigintensive Nudges: Informationsbereitstellung wie Peer-Vergleiche

- **Low-level nudges** focus primarily on information delivery, such as sending clinicians comparative performance emails that show how their metrics stack up against those of colleagues within their organisation [5].

- **Mid-level nudges** employ more sophisticated approaches by either presenting existing information in new formats or eliciting specific implementation intentions, i.e. detailed plans specifying when, where, and how a target behaviour will be performed. Precommitment strategies ("voluntary, advance restrictions on future choices") exemplify this approach, having demonstrated effectiveness in reducing inappropriate antibiotic prescribing by prompting clinicians to formalise their treatment intentions explicitly [5].

mittelintensive Nudges: neue Informationsformate und Selbstverpflichtungs-Strategien

- **High-level nudges** operate directly at the decision point, either by requiring active choice or establishing evidence-based options as defaults. Though more assertive, these upper-tier nudges typically prove more effective than lower-level interventions and can better address electronic health record (EHR) design flaws that contribute to decision errors, such as over-prescribing branded medications when equally effective, less expensive generics are available. Default modifications are particularly appropriate when both clinicians and patients have minimal preference between options and when evidence supports the default choice [5].

hochintensive Nudges: aktive Wahlpflicht oder evidenzbasierte Standardeinstellungen in der Entscheidungssituation

Frameworks

Behaviour change frameworks transform complex behavioural science into practical tools that help policymakers and healthcare executives implement evidence-based interventions. These frameworks compress psychological insights into accessible formats, enabling organisations to address human decision-making challenges systematically [21]. These frameworks facilitate the design of interventions by making desired behaviours easier, more appealing, and aligned with social norms and optimal timing. Implementation typically involves defining the target behaviour, identifying barriers, and applying design techniques such as establishing beneficial defaults, simplifying choice options, and providing timely prompts. The following section outlines some applied frameworks in the healthcare sector that provide structured approaches to designing behaviour-change interventions.

Frameworks zur Verhaltensänderung übersetzen Verhaltenswissenschaft in praktische Implementierungstools

Theoretical Domains Framework

The Theoretical Domains Framework (TDF) is a comprehensive theoretical framework developed to help researchers and practitioners understand and predict behaviour change, particularly in healthcare and implementation science contexts [7]. Developed through expert consensus in 2005 and refined in 2012, it synthesises 33 psychological theories into 14 key domains (see Figure 1-2) that influence human behaviour [15, 16] (see Table A-2) in the Appendix for a more detailed description of the domains).

Theoretical Domains Framework (TDF): 14 Schlüsseldomänen zur Verhaltensvorhersage

The TDF is frequently used to identify barriers and facilitators in the design and implementation of nudging strategies. By examining the psychological, social, and environmental determinants of target behaviours, the TDF enables researchers and practitioners to pinpoint specific factors that either hinder or promote behaviour change. This comprehensive assessment then guides the strategic selection and tailored design of appropriate nudging techniques that address the identified behavioural determinants, ultimately enhancing the effectiveness of intervention strategies [8, 22].

Identifizieren von Barrieren und Förderfaktoren für zielgerichtetes Nudging-Design

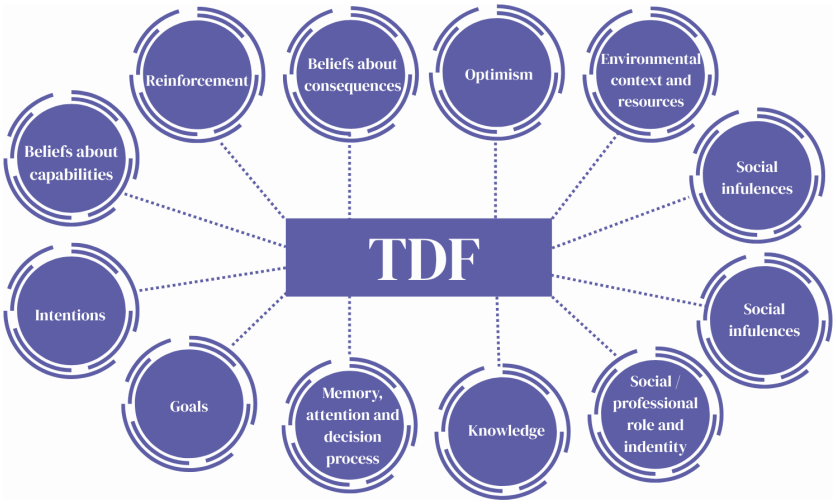


Figure 1-2: TDF key domains

MINDSPACE framework

MINDSPACE-Framework: 9 Verhaltens-komponenten

The MINDSPACE framework was developed by the UK's Cabinet Office and the Institute for Government, led by a team of behavioural scientists. It has since been widely applied across government strategy, health care, commercial promotion, organisational change, and personal development [23]. This framework highlights nine critical components that drive behaviour (see Figure 1-3 and Table A-3 in the Appendix for a more detailed description of the components).

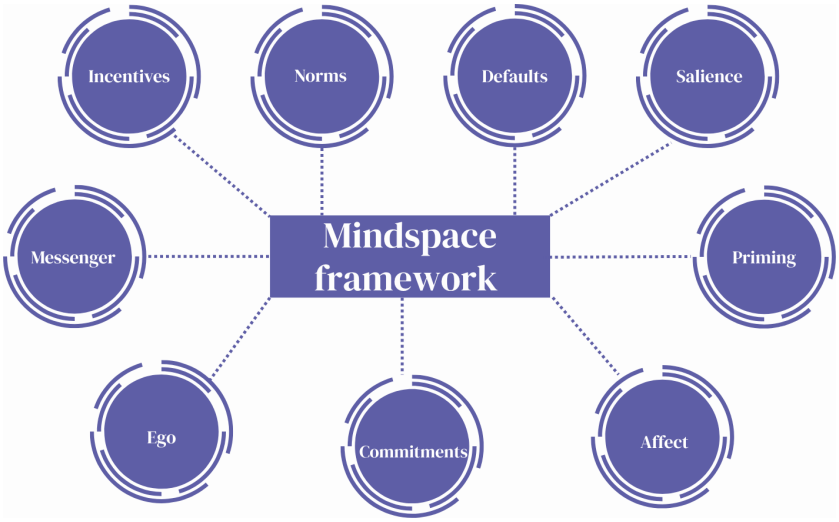


Figure 1-3: Components of the Mindspace framework

Ergänzung bestehender Ansätze und Identifizierung von Barrieren für Verhaltensänderung

The components can be used to enhance current behaviour change efforts, introduce innovative behavioural science concepts with public consent and avoid unintended behavioural influences [23]. The framework augments rather than replaces existing policy development approaches, incorporating behavioural scholarship to strengthen and enhance governmental planning procedures. Additionally, MINDSPACE can help uncover barriers currently hindering behavioural modifications [17, 23].

EAST framework

EAST-Framework: 4 Prinzipien zur Anwendung verhaltenswissenschaftlicher Erkenntnisse

Developed by the Behavioural Insights Team, a team established within the UK government in 2010 as the world's first institution dedicated to incorporating behavioural insights into public policy [24], the EAST framework offers policymakers a straightforward approach to applying behavioural science. It employs nudging and psychological methods to enhance public policy, guided by four key principles (see Figure 1-4 and Table A-4 in the Appendix for a detailed description) [25].

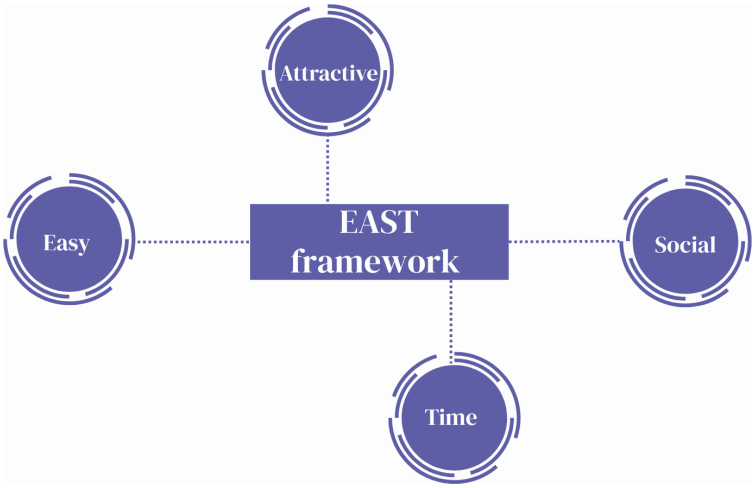


Figure 1-4: Key principles of the EAST framework

Implementierungsintentionen adressieren Umsetzungslücken durch systematische Aktionspläne

These principles integrate behavioural science research with practical implementation experience to create a structured intervention framework [18]. Implementation failures often occur despite good intentions due to implementation gaps rather than conceptual flaws. This can be addressed through "implementation intentions" – systematic action plans that anticipate barriers and specify solutions [25].

Vier-Stufen-Prozess:

The Behavioural Insights Team advocates a four-stage implementation process:

1. **Define outcomes**: Establish specific, measurable objectives that clearly articulate desired behavioural changes — **1. Zielsetzung,**
2. **Analyse context**: Conduct a thorough situational assessment to identify potential unintended consequences and contextual constraints — **2. Kontextanalyse,**
3. **Design intervention**: Develop the behavioural intervention based on evidence and contextual understanding — **3. Interventionsdesign und**
4. **Iterate and adapt**: Implement continuous testing and refinement cycles to optimise intervention effectiveness based on real-world performance data. — **4. iterative Anpassung**

FORGOOD framework

FORGOOD-Framework: 7 Prinzipien für ethische Entscheidungsfindung

The FORGOOD framework provides a systematic approach to ethical decision-making in behavioural interventions, applicable across public policy and corporate healthcare settings. The framework is built on seven core principles (see Figure 1-5).

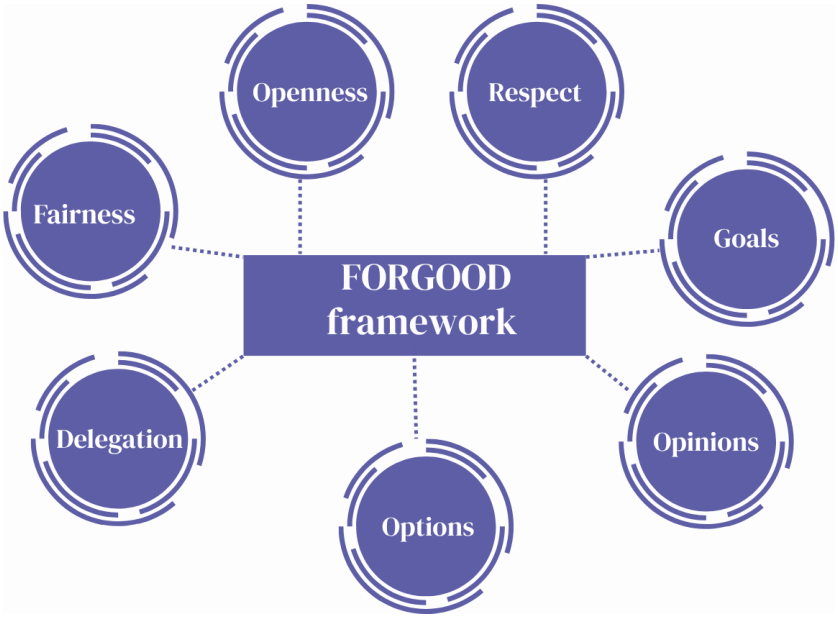


Figure 1-5: Core principles of the FORGOOD framework

strukturiert ethische Abwägungen und ermöglicht transparente, kontextspezifische Entscheidungen

The principles help decision-makers balance ethical considerations with practical implementation needs (see Table A-5 in the Appendix) [19, 26]. FORGOOD synthesises the literature on responsible behavioural science use and ethical philosophy into a manageable, memorable framework. Rather than serving as a simple checklist, it provides a structure for evaluation and decision-making, acknowledging that practical ethics are contextually situated and often involve trade-offs. By prompting targeted questions for review bodies, the framework highlights key ethical issues that require discussion, mitigation, acceptance, or rejection. It can be adapted to align with each organisation's strategy, values, and goals whilst providing a clear audit trail for independent review [19].

1.2.2 Evaluating implemented nudges

wissenschaftliche Evaluation vor und nach Implementierung sichert Nudge-Effektivität

Rigorous scientific evaluation, both before and after implementation, remains fundamental to ensuring the effectiveness of nudges, as emphasised throughout various theoretical frameworks. Healthcare settings offer substantial opportunities to implement expanded nudging through systematic design processes, comprehensive evaluation methodologies, and evidence-based assessment protocols [5, 8, 9].

Penn Medicine Nudge Unit: umfassende Forschung zu klinischer Effektivität und operativer Umsetzbarkeit

The Penn Medicine Nudge Unit exemplifies this research-driven approach, conducting comprehensive evaluations of nudging effectiveness, feasibility, and implementation across multiple healthcare domains. With over a decade of experience, their research portfolio addresses critical areas including antibiotic stewardship, preventive care optimisation, medication adherence, clinical decision support integration, provider behaviour modification, and patient engagement strategies. Their investigations systematically examine how behavioural science principles can improve healthcare outcomes while addressing practical implementation challenges in complex healthcare systems, emphasising a dual assessment of both clinical effectiveness and operational viability [27].

1.3 Nudging within the Austrian healthcare system

begrenzte Nudging-Implementierung in Österreich (Ö);

Beispiele: Widerspruchslösung bei Organspenden, Mammografie einladungen …

The application of behavioural economic theories and methodologies within healthcare systems is unsterilised both globally and domestically within Austria, representing unrealised implementation potential [28]. The former Social Insurance Institution for Business (Sozialversicherungsanstalt der gewerblichen Wirtschaft; SVA) functioned as an early adopter, operationalising behavioural economic frameworks through systematic nudge interventions specifically targeting preventive healthcare behaviours [28]. These include an organ donation system that utilises an opt-out (presumed consent) framework, in which all citizens are automatically registered as potential organ donors unless they explicitly opt out. Another example is the social insurance-wide mammography invitations for women aged 45-69, which function as nudges promoting breast cancer prevention [28].

… und eEKO

Another currently used approach in the Austrian healthcare sector is the electronic reimbursement code (eEKO), which was designed to support physicians in selecting the most cost-effective medication from several therapeutically suitable options when prescribing drugs. This was intended to facilitate compliance with guidelines for the economical prescribing of therapeutic products and medications; however, the final decision on which medications were therapeutically appropriate in specific cases remained the responsibility of the prescribing physicians. It enables physicians to obtain an overview of therapeutic alternatives in the reimbursement codex and a display of prices within the comparison group, including list prices, when entering a product name or active ingredient [29].

weitere Möglichkeit: Nudging zur Verschreibungsoptimierung

While Austria has already introduced various initiatives that incorporate nudging principles into health policy measures, there may be further opportunities for introducing nudges, for example, in prescribing optimisation.

1.4 Nudging and prescription optimisation

Verschreibungspraxis trotz Leitlinien suboptimal

Antibiotikaresistenz durch Überverordnung steigend

erhöhte Kosten für Gesundheitssysteme

Prescribing represents the most frequently employed patient-level intervention in healthcare systems worldwide [30]. The pressure to comply with clinical and administrative guidelines has intensified considerably in recent years, a development aimed at optimising the quality of patient care while simultaneously reducing costs [31]. However, despite or even because of the many different evidence-based guidelines for prescribing, decisions remain complex and are made under time pressure and patient expectations. Even experienced clinicians may deviate from best practices, particularly in uncertain areas like opioid or antibiotic prescribing. Antibiotic overprescription illustrates the severity of suboptimal prescribing. WHO surveillance reveals an escalating global crisis: between 2018 and 2023, resistance increased in over 40% of monitored pathogen-antibiotic combinations, rising by five to 15% annually. In the USA, approximately 25% antibiotic prescriptions are unnecessary, contributing to 2 million infections and 23,000 deaths from resistant bacteria annually, adding £20 billion to healthcare costs [31].

zunehmende Medikamentenvielfalt und Multimorbidität erschweren angemessene Verschreibung

Further, the exponential growth in licensed medicinal products throughout the past century, driven by significant advances in clinical pharmacology and pharmaceutical research, has rendered prescribing an increasingly complex clinical task. This complexity is further compounded by the rising rates of multimorbidity within ageing populations, often resulting in potentially inappropriate polypharmacy practices [30].

WHO-Ziel: Halbierung medikamentenbedingter Schäden durch Schulung und digitale Unterstützungssysteme

Ensuring safe medication use presents a considerable challenge for contemporary healthcare systems. In recognition of this, the World Health Organisation established an ambitious global target to reduce medication-related harm by 50% by 2022 [32]. Healthcare systems have responded by implementing comprehensive strategies to support prescribers in minimising prescribing errors. These interventions encompass educational programmes and professional development, enhanced interprofessional communication and collaborative support mechanisms, and the integration of digital technologies incorporating clinical decision support tools (CDST) [30].

Nudging zur Verbesserung der Verschreibungsqualität

Interventions that incorporate findings from the behavioural sciences are gaining increasing prominence as approaches to enhance the quality of medical decision-making processes [33, 34]. Within this context, the concept of "nudging" has garnered particular attention as a mechanism for addressing suboptimal prescribing practices, such as inappropriate antibiotic use or excessive opioid prescribing. Nudging offers potential solutions by simplifying information processing (e.g., presenting guidelines in plain language) while preserving healthcare professionals' decision-making freedom, as nudges influence without removing choice [31].

1.5 Research questions

Considering the information outlined above, this project aims to systematically categorise nudging strategies in healthcare that can positively influence the prescribing behaviour of physicians. This involves documenting implemented approaches from the literature and evaluating them for their effectiveness. A further focus lies in analysing the transferability of these strategies to the context of the Austrian healthcare system. This leads to the following three research questions (RQ):

3 Forschungsfragen (FF):

1. Which nudges for optimising prescribing behaviour have been implemented and evaluated internationally, and how can they be categorised?
2. How effective and safe are the nudges described in international literature for optimising prescribing behaviour?
3. Which nudges have proven to be effective and safe internationally and would be suitable for implementation in the Austrian healthcare system? What criteria should be considered for successful implementation in the Austrian context?

1. Identifizierung und Kategorisierung von Nudges,

2. Wirksamkeit und Sicherheit,

3. Implementierbarkeit im österreichischen Kontext

2 Methods

2.1 Systematic review (RQ1 + RQ2)

Systematischer Review (SR) nach PRISMA-Leitlinien mit Protokollabänderungen:

To address *research question one* (identifying nudges and categorisation systems) and *research question two* (effectiveness and safety), we conducted a systematic review following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [35]. Some deviations from the registered protocol (https://doi.org/10.17605/OSF.IO/AB6S3) were necessary during the review process:

- We refined the inclusion criteria to increase specificity following the initial search, which yielded a substantially higher number of studies than anticipated.

  Einschlusskriterien nachträglich präzisiert

- The included studies in research question one provided no categorisation frameworks for classifying the identified nudges, necessitating hand searching for another taxonomy.

  fehlende Klassifikationssysteme: zusätzliche Handsuche

- We opted not to assess the certainty of evidence using the GRADE approach [36] in our analysis of nudge-style interventions because such behavioural strategies are inherently context-sensitive, complex, and often evaluated using field experiments or mixed methods, which do not align well with GRADE's default assumptions. GRADE is optimised for clinical or treatment interventions with well-defined outcomes, homogeneous settings, and quantitatively pooled evidence. Applying it rigidly to nudges can lead to systematic downgrading of evidence that is nonetheless informative in real-world settings. Given this pattern of, relatively small, context-bound effects, heterogeneity in implementation, and sensitivity to environmental conditions, we judged that GRADE's downgrading rules (for issues like indirectness, imprecision, or inconsistency) would obscure, rather than clarify, the utility of the evidence.

  Verzicht auf GRADE-Ansatz

Literature search

To identify high-quality systematic reviews, a preliminary literature search was conducted in Ovid Medline on 22 April 2025 (the search strategy is available in the protocol https://doi.org/10.17605/OSF.IO/AB6S3), supplemented by manual searching in reference lists and PubMed[1]. This search yielded 19 systematic reviews, of which two (Talat, 2022 [37] & Hallett, 2024 [8]) were considered potentially relevant. Both underwent independent assessment by three reviewers (VH, JAP, TM) using the ROBINS tool [38]. Due to methodological limitations identified in each study, neither was deemed suitable as a foundation for an updated review. This determination led to the decision to focus on primary studies for the present investigation.

eingeschränkte Qualität identifizierter SRs: Fokus auf Primärstudien

Although neither systematic review met the quality criteria for updating, the literature search methodology employed by Talat (2022) [37] received a favourable assessment from an information specialist (TM) using the ROBINS tool. Consequently, an updated search was conducted covering the period fol-

systematische Literatursuche in Medline, Cochrane, Embase und INAHTA

[1] https://pubmed.ncbi.nlm.nih.gov/ (accessed: 14.10.2025)

lowing the original review's search end date (June 2019). This updated systematic literature search was performed on 7 to 8 June 2025 in the following databases:

- Medline
- Cochrane
- Embase
- HTA (INAHTA)

Verfügbarkeit von Suchstrategien

The search strategy for Ovid Medline is included in the appendix (see Table A-1). The search strategies for the other databases are available in the OSF database (https://doi.org/10.17605/OSF.IO/AB6S3) or upon request from the authors.

Handsuche und RCTs aus bestehenden Reviews ergänzen systematische Literatursuche

Additional studies were identified through screening of the reference lists of identified studies by one author (VH). These studies, along with the randomised controlled trials (RCTs) identified in the Hallett [8] and Talat [37] reviews, were incorporated into the PRISMA flow diagram (see Figure 2-1) under "additional records identified through hand search".

zusätzliche Handsuche zur Identifikation geeigneter Kategorisierungssysteme

The primary studies identified through the systematic literature search provided insufficient information to support nudge categorisation, necessitating a supplementary manual search by one author (VH) to identify suitable classification frameworks.

Inclusion criteria

PIKO-Frage

To identify nudges and categorisation systems *(research question one)* and effectiveness and safety *(research question two)*, relevant literature was selected based on the PICO criteria outlined in Table 2-1.

Table 2-1: Inclusion criteria for RQ1 + RQ2

	Included	Excluded
Population	Addressees of the intervention, e.g., general practitioners, medical specialists	Dentists, intensive care staff, nursing home staff, and long-term care staff[2]
Intervention	Nudges (incentives to change behaviour) ... ... which can optimise the prescribing behaviour of medical staff ... ... to optimise the quality of patient care and reduce costs ... ... and have already been implemented internationally.	Nudges aimed at patients/relatives and nudges aimed at medical staff and patients/relatives at the same time
Control	Standard procedures (e.g. economic incentives, prohibitions/bids) or other comparators	Nudges aimed at patients/relatives and nudges aimed at medical staff and patients/relatives at the same time

Outcomes	**Research question 1:**
	■ Characteristics of nudges used internationally
	■ Categories for categorising identified nudges
	Research question 2:
	■ Effectiveness and safety of the nudges in relation to, e.g.:
	  ■ Optimisation of prescriptions of certain medication groups (e.g. change in the number of prescribed medications/prescription rates, reduction of large prescription quantities, new prescriptions)
	  ■ Undesirable side effects (e.g. adverse events, hospitalisation)
	  ■ Implementation of the measures (e.g. effort, feasibility, costs)	

[2] These settings were excluded as they represent highly specialised care contexts with distinct prescribing practices.

	Included	Excluded
Publication type	**Research question 1 + 2:** ■ Systematic reviews ■ Primary studies	
Countries	Europe, North America, Australia, New Zealand	Asia, South America, Africa[3]
Publication period	No restriction	
Languages	English, German	

Abbreviation: e.g. … exempli gratia

strenge Einschlusskriterien für Abstrakt- und Volltext-Screening

Due to the high number of studies identified, the abstract screening was restricted to RCTs only. At the full-text review stage, additional stringent inclusion criteria were applied to further refine the pool of eligible studies:

- Intervention objective: Clear description of the study's primary aims and intended behavioural outcomes.
- Compliance with the definition of nudges: "any aspect of the choice architecture that predictably alters people's behaviour without forbidding any options or significantly changing their economic incentives".
- Behavioural science foundation: Description of the nudge's underlying behavioural science principles and theoretical basis.
- Primary outcome relevance: Direct applicability of the study's main outcome measures to our research objectives.
- Extended study duration: Evaluation period exceeding 12 months and more to assess the long-term effectiveness and sustainability of the nudging intervention.

Literature Selection

1.447 Referenzen identifiziert

unabhängiges Screening durch 2 Autorinnen

The literature search retrieved 1,447 sources for selection. The abstracts were screened independently by two reviewers (VH, JAP). Considering the PICO criteria (see Table 2-1), 1,394 sources were excluded based on their abstracts. The remaining 53 full texts were assessed by one author (VH) using the additional key inclusion criteria defined, and the decision was reviewed by the second author (JAP). Uncertainties regarding the selection were resolved through discussion and consensus with the co-author (JAP), or by involving a third person (JMF). The selection process is illustrated in Figure 2-1:

[3] Studies from Asia, South America, and Africa were excluded as these regions have substantially different healthcare system structures, resource availability, and regulatory frameworks compared to the Austrian healthcare context.

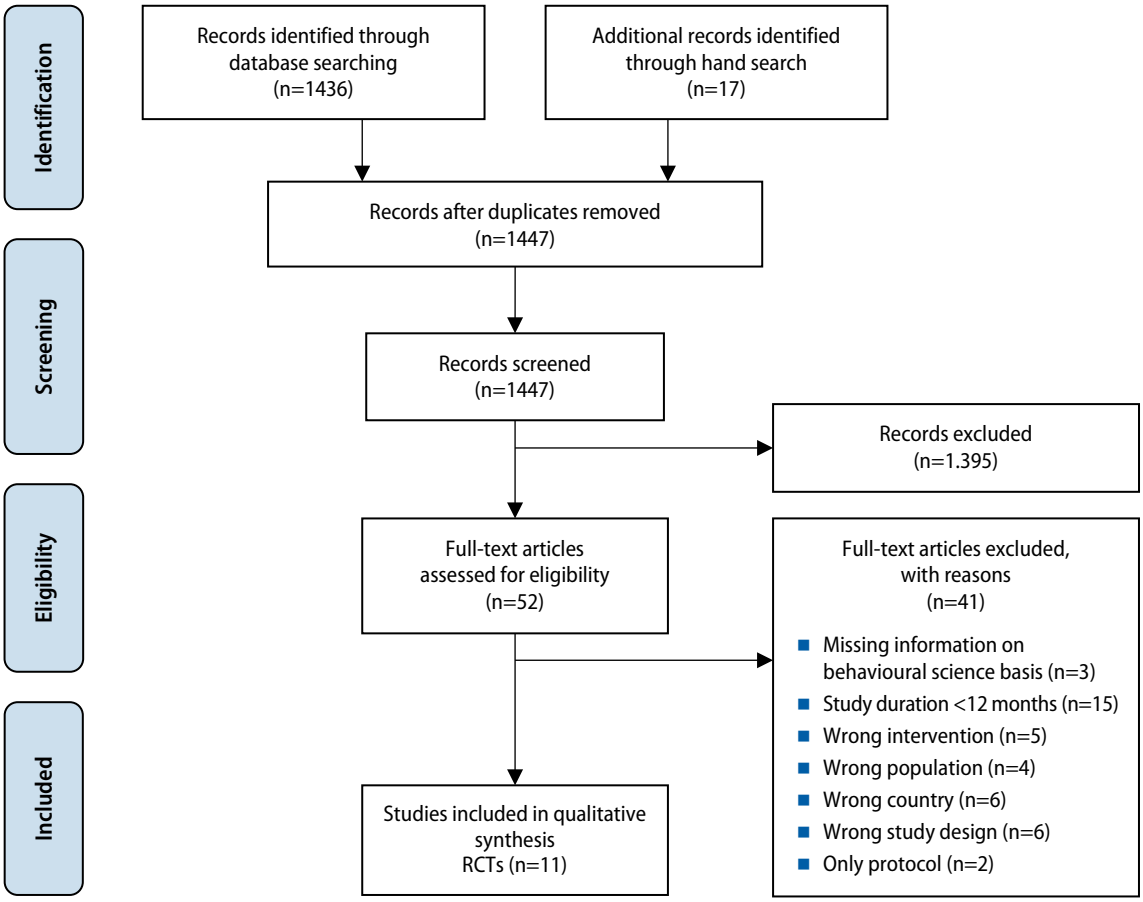


Figure 2-1: Illustration of the selection process (PRISMA Flow Diagram)

Data extraction and analysis

Datenextraktion zu Nudging-Interventionen und narrative Analyse

Following literature selection, data on nudging interventions and their characteristics (*RQ1*) were extracted from the included RCTs. The extracted information was tabulated and analysed narratively.

Kategorisierung nach:

For the classification of nudges, we employed three categorisation systems, to which we assigned the extracted data:

1. **Nudge intensity clustering:** The nudge intervention ladder (see Nudge Intervention Ladder) was applied to categorise interventions according to their intensity levels (high, mid, low) [14]. **Intensität mittels Nudge-Intensitätsleiter,**
2. **Behavioural change factors:** Nudges were classified according to their targeted behavioural change mechanisms using the Theoretical Domains Framework (see Theoretical Domains Framework) [37]. **Verhaltensänderungs-mechanismen mittels TDF,**
3. **Behavioural drivers:** Interventions were categorised based on the specific behavioural drivers they address, as defined by the MINDSPACE framework (see MINDSPACE framework) [37]. **Verhaltenstreibern mittels MINDSPACE**

The classification, based on the Theoretical Domains Framework and MINDSPACE framework, was adopted from a systematic review [37] identified during the preliminary search for systematic reviews. **TDF- und MINDSPACE-Klassifikation aus identifiziertem SR übernommen**

To evaluate the evidence of benefits and harms of nudges (*RQ2*), further information from the identified RCTs was extracted into tables and analysed narratively. These tables were organised according to prescribed drug categories (antibiotics, opioids, and other medications). The tables include information on the effectiveness, harms, economic and implementation outcomes of the identified nudging interventions.

Evidenzbewertung nach Medikamentenkategorien: Wirksamkeit, Sicherheit, Ökonomie und Implementierung

Data synthesis

A qualitative synthesis of evidence was conducted to identify nudging interventions (*RQ1*), with data interpreted according to the three categorisation systems. Categorisation findings are presented through a narrative synthesis of the tabulated data.

qualitative Evidenzsynthese und Kategorisierung nach 3 Klassifikationssystemen

To evaluate the effectiveness and safety of the identified nudges (*RQ2*), the extracted information was synthesised narratively. Results are reported according to drug group (antibiotics, opioids, and other medications), with intervention groups stratified by nudge intensity level (high, mid, and low) to facilitate more precise interpretation (see nudge intensity clustering in the Methods section).

Evidenzbewertung nach 3 Medikamentengruppen und 3 Nudge-Intensitätsstufen

Quality assessment

The data extraction and categorisation of the nudges were conducted by one author (VH) and cross-checked by a second author (JAP). Discrepancies were resolved through consensus discussion.

Cross-Check der Datenextraktion

We used the Risk of Bias tool 2 [39] to assess the risk of bias of the outcomes of the individual studies. The quality assessment was conducted by one author (VH) and verified by the second author (JAP).

Bewertung des Risikos für Verzerrungen (RoB) der Ergebnisse

2.2 Expert consultation (RQ3)

To answer the *third research question*, which explores the implementation requirements and barriers to effective nudging interventions within Austria, we conducted an expert consultation. Ethical approval was not required as the study involved experts rather than patients or vulnerable populations. The reporting of this study adheres to the COREQ (Consolidated Criteria for Reporting Qualitative Research) guidelines [40].

FF3: Expert:innenbefragung zur Implementierung in Österreich

Survey

We developed a German-language questionnaire comprising open-ended questions, derived inductively from *RQ2*, to explore the feasibility of implementation and anticipated barriers in Austrian healthcare settings.

Expert:innenbefragung via Online-Fragebogen

Following a pilot test with two AIHTA team members, the questionnaire (see Appendix: Table A-16) was administered via email to four social insurance experts who had been recommended by the Department for Contractual Partners Pharmaceuticals in the Federation of Social Insurances ("*Fachabteilung der Vertragspartner Medikamente im Dachverband der österreichischen Sozialversicherung*"). The email contained a link and QR code to the online consultation

(created using LimeSurvey.org[4]), which was active from 20 August until 22 September 2025.

Data analysis and synthesis

thematische Analyse zur Implementierung, Information und Akzeptanz

Qualitative responses were transferred to MaxQDA[5] for analysis and interpretation. Three primary categories (implementation, general information, and practitioner acceptance) were used for coding the answers. Coding was performed by one author (VH) and cross-checked by a second author (JAP). The coding served exclusively to identify common themes across questionnaires and to streamline the documentation. The responses to the given questions were subsequently synthesised and documented narratively.

2.3 Quality assurance

Qualitätssicherung

As part of the quality assurance process, the report was reviewed by two internal reviewers (JMF, IZK) and one external reviewer (EW).

The external reviewer was asked to assess the following quality criteria:

- Technical correctness: Is the report technically correct (evidence and information used)?
- Does the report consider the latest findings in the research area?
- Adequacy and transparency of method: Is the chosen method adequate for addressing the research question, and are the methods applied transparently?
- Logical structure and consistency of the report: Is the report's structure consistent and comprehensible?
- Formal features: Does the report fulfil formal criteria of scientific writing (e.g. correct citations)?

The AIHTA considers external peer review by scientific experts from different disciplines a quality assurance method of scientific work. The responsibility for the report content lies with the AIHTA.

[4] https://www.limesurvey.org/de (accessed: 29.09.2025)

[5] https://www.maxqda.com/de/ (accessed: 29.09.2025)

3 Results

3.1 Identified nudges and categorisation (RQ 1)

3.1.1 General study characteristics

For this systematic review, eleven RCTs [41-51] examining nudging interventions across antibiotic (n=5, [41-44, 51]), opioid (n=3, [45, 46, 50]), and other medication prescribing (n=3, [47-49]) were included. Publication years ranged from 2016 to 2024, with four studies each conducted in the United Kingdom [41, 42, 47, 49] and the United States [43, 45, 46, 50], and one study each in Canada [51], France [44] and across multiple European countries [48]. Five studies compared a one-nudge intervention with a control group [41, 42, 47, 48, 50] (whereby the nudges in these studies typically comprised multiple components), and six studies [43-46, 49, 51] compared two or more nudging interventions against control conditions. Study durations varied from twelve to 24 months. The studies varied considerably in scale, from 44 medical practices to over 2,500 medical practices included as target population, with patient populations ranging from approximately 3,900 to over 330,000. Patient populations varied by study focus: antibiotic studies included children up to nine years old, adults without age restrictions, and older adults aged 65 and above; opioid studies primarily had adults as the patient population; and other medication studies focused on adults, with one specifically examining patients aged 75 years and older. The interventions addressed diverse prescribing challenges, including antibiotic stewardship for respiratory tract infections, opioid reduction strategies across surgical and emergency settings, and optimisation of cardiovascular medications, polypharmacy management, and high-risk medication prescribing, including antipsychotics and non-steroidal anti-inflammatory drugs. The taxonomies of interventions and their respective control parameters are systematically outlined in Appendix, Table A-9.

11 RCTs aus UK, USA und Europa zur Verschreibungsoptimierung bei Antibiotika (n=5), Opioiden (n=3) und sonstigen Medikamenten (n=3)

Studien mit 44 bis 2.500 Praxen und mit 3.900 bis über 330.000 Patient:innen

heterogene Studienpopulationen: Kinder bis Senior:innen,

Studiendauer 12-24 Monate

3.1.2 Identified nudges

Overall, 22 nudges were identified in the included RCTs (n=11). Table 3-1 presents an overview of the individual nudging interventions and their comparators. The following four nudges emerged as most prevalent:

22 Nudging-Interventionen identifiziert

Peer comparison, the most prevalent nudging mechanism, is a feedback intervention that shows physicians how their performance (e.g., prescribing rates, clinical outcomes) compares to that of their colleagues or peers, typically to encourage alignment with best practices or group norms. It was implemented independently [43, 45, 46] or in conjunction with complementary interventions [43, 45, 46, 49, 51]. Multi-component implementations typically combined peer comparison with individualised audit feedback, educational newsletters addressing high-risk prescribing, and colour-coded performance visualisation systems. Some interventions employed harm communication strategies, using data visualisation or prescription alerts, which required justification for outlier prescribing patterns.

Peer-Vergleich (= Leistungsvergleich mit Kolleg:innen) als häufigstes Nudge; eigenständig oder mit Feedback und Schulung kombiniert

klinische Entscheidungsunterstützungssysteme (CDST) einzeln oder kombiniert mit anderen Nudges

Clinical decision support tools were used alone [48] or in combination with other nudging strategies [41, 42, 44]. This framework leverages a computational decision support infrastructure, encompassing integrated clinical practice guidelines, systematic pharmaceutical risk assessments, and automated alert mechanisms, to facilitate evidence-based prescribing optimisation while preserving physician discretion in ultimate medication selection decisions.

Dokumentationspflicht bei Verschreibung

Accountable justification was assessed both independently [43] and as a component of multi-faceted approaches [43, 45]. The intervention architecture encompasses the following elements: Automated clinical decision support prompts embedded within electronic medical record systems that activate upon antibiotic prescribing attempts. The intervention mandates explicit written clinical justification for prescribing decisions, with documentation permanently archived as visible annotations within patient medical records. System protocols generate default "no justification provided" entries when clinicians fail to complete required fields. Workflow completion is contingent upon prompt acknowledgement, whilst preserving clinician autonomy to support prescriptions rather than provide mandatory documentation.

Schulungsbesuche in Praxen

Educational outreach interventions were delivered through health insurance representatives (HIR) conducting structured educational visits to primary care facilities [44, 47]. The interventions encompassed three core components: dissemination of evidence-based information addressing antibiotic resistance mechanisms, optimal antibiotic stewardship practices, and guideline-concordant prescribing behaviours; provision of benchmarked prescribing feedback incorporating individual practitioner data contextualised against regional and national prescribing patterns; and distribution of clinical decision aids specifying evidence-based antibiotic treatment algorithms for cystitis and pharyngotonsillitis.

Table 3-1: Overview table presenting the identified nudges and their comparators, structured by medication type

Study	Intervention (Nudge)	Comparator
Antibiotics		
Blair, 2023 [41]	**Chico intervention**: Eliciting explicit carer concerns during consultation, clinician-focused algorithm to predict risk of hospitalisation for children with RTI, carer-focused personalised printout	No intervention
Gulliford, 2019 [42]	**Multicomponent intervention**: Webinar, antibiotic prescribing reports, CDST	No intervention
Meeker, 2016 [43]	**Suggested alternatives:** EHR-based CDST with a list of alternative treatments	No intervention
	Accountable justification: EHR-based, requires an explicit written explanation for the prescribing decision	
	Peer comparison: Monthly Email-based intervention, regional ranking	
	Suggested alternatives + peer comparison	
	Accountable justification + peer comparison	
	Suggested alternatives + accountable justification + peer comparison	
Jeanmougin, 2024 [44]	**Feedback visits:** Visit with prescription feedback	Routine visit by the regional HIR
	Feedback visit and CDST: Visit with prescription feedback and a CDST demonstration on antibiotic prescribing	

Study	Intervention (Nudge)	Comparator
Schwartz, 2024 [51]	**Mailed letter**[6]**:** ■ *Case-mix adjusted:* risk-adjusted comparison, case-mix adjusted, standardised peer comparison ■ *Unadjusted data:* feedback on raw antibiotic prescribing with peer comparison ■ *Harms messaging:* infographic highlighting the frequency of side effects and harms associated with antibiotics ■ *Non-harms:* infographic on the lack of benefits from unnecessary antibiotic prescribing.	No intervention
Opioids		
Dun, 2023 [50]	**Individualised peer comparison report:** benchmarked feedback report, individualised performance dashboard, peer comparison scorecard	No intervention
Kreamer, 2022 [45]	**Alert + justification:** Alert with guideline checklist requiring free-text justification for opioid prescribing decisions	Alert containing a guideline with a short checklist of recommendations
	Peer comparison group: monthly feedback via e-mail	
	Alert + justification + peer comparison	
Navathe, 2022 [46]	**Individual audit feedback:** implemented by informing clinicians that the health system was reviewing opioid prescriptions with a high number of pills	No intervention
	Peer comparison feedback: informing clinicians of their opioid prescribing during the prior three months relative to that of their practice site peers	
	Individual audit feedback + peer comparison feedback	
Other medication		
Presseau, 2018 [47]	**Behavioural change-focused outreach intervention**[7]**:** facilitated action planning, barrier-focused implementation workshop, tailored behaviour change coaching	No intervention
Rieckert, 2020 [48]	**CDST:** a tool providing a comprehensive drug review generated from patient data recorded in the electronic case report form	No intervention
Guthrie, 2016 [49]	**Educational newsletter + peer comparison feedback:** feedback on prescribing benchmarked rate sent from the NHS Scotland Information Services Division	No intervention
	Educational newsletter + peer comparison feedback and one-page theory-informed behavioural change component: feedback on prescribing benchmarked rate sent from the NHS Scotland Information Services Division + information about behavioural change	

Abbreviations: CDST … clinical decision support tool; EHR … electronic health records; HIR … health insurance representative; NHS … National Health Service; RTI … respiratory tract infection

3.1.3 Categorisation

Klassifikation nach …

In general, nudges are taxonomically classified to establish a systematic framework for their understanding and practical implementation, facilitating the identification of distinct behavioural intervention types, monitoring of their outcomes, and organisation of research and policy initiatives across domains, including health, finance, and education. Various classification systems exist, including categorisation based on exploited cognitive heuristics (exemplified by the MINDSPACE framework) or classification according to their individual and societal impact.

[6] Following Schwartz et al.'s (2024) [51] analytical approach, which combined the four intervention groups (case-mix adjusted feedback, unadjusted feedback, harms messaging and non-harms messaging) for comparison against control, we similarly report these as a single nudge intervention in our results.

[7] This study targeted the improvement of type 2 diabetes management in primary care including outcomes on glucose-lowering and antihypertensive medication prescribing, foot examinations, and patient education.

For categorisation, we employed three different classification modes:

1. Classification by intensity level ("Nudge Intervention Ladder": low-, mid-, high-level),
2. Behavioural change factors ("Theoretical Domains Framework"),
3. Behavioural drivers ("MINDSPACE framework").

… Intensität,

… Verhaltens-änderungsfaktoren und Verhaltenstreibern

For a comprehensive description of the Nudge Intervention Ladder, the Theoretical Domains Framework and the MINDSPACE Framework, the reader is directed to the Chapter "Choosing the right nudge".

1. Intensity level

Most nudges, totalling eleven, can be classified as low-level, seven as mid-level, and four as high-level interventions. Table 3-2 presents the categorisation of identified nudges according to their intensity level.

11 niedrig- (⇩), 7 mittel- (⇔), 4 hochintensive (⇧) Nudges

Low-level interventions primarily involved feedback visits providing comparative prescribing data [44, 51], standardised letters with benchmarking information [45, 46, 51], audit feedback systems [45, 46], behavioural change-focused outreach sessions [49], and educational newsletters with peer comparison elements [47].

⇩ Nudges, z. B. Peer-Vergleich

Mid-level interventions included EHR-based pop-ups that suggested alternatives, provided justification requirements for prescribing decisions, featured peer comparison rankings, and combined alert systems with monthly feedback mechanisms [43, 45, 46].

⇔ Interventionen, z. B. Dokumentationspflicht bei Verschreibung

High-level interventions comprised sophisticated CDSTs, such as algorithms for predicting hospitalisation risk in children with respiratory tract infections, comprehensive multicomponent programmes combining webinars, prescribing reports, and decision support tools, and computerised decision support tools for comprehensive drug reviews requiring extensive system integration and stakeholder coordination [41, 42, 44, 48, 50]

⇧ Interventionen, z. B. CDST

2. Behavioural change factors

Most interventions employed multi-domain strategies, typically combining cognitive factors (such as memory, attention, and decision processes) with social influences and motivational elements (such as goals and emotions). Table 3-2 presents the categorisation of identified nudges according to the Theoretical Domains Framework. The most frequently applied domains were:

Multi-Domain-Strategien kombinieren kognitive, soziale und motivationale Faktoren

Emotional mechanisms were observed via 22 nudges, primarily focusing on enhancing motivation through affective priming strategies. These interventions employed visual performance indicators and recognition systems to create emotional engagement with prescribing behaviours. For example, one nudge [50] employed a colour-coded performance categorisation system, exemplifying this approach through red outlier flagging that creates immediate affective responses. Meanwhile, another nudge [51], presenting an infographic of antibiotic-associated adverse events, utilises fear-based messaging to modify emotional associations with prescribing decisions.

emotionale Mechanismen (22 Nudges)

The *behavioural regulation* domain, related to 17 nudges, frequently co-occurred with goal-setting mechanisms, reflecting the theoretical integration of self-monitoring frameworks with the formation of implementation intentions. For example, in one intervention, 90-minute structured behaviour change sessions demonstrate comprehensive behavioural regulation through systematic per-

Verhaltensregulation (17 Nudges)

formance gap analysis and barrier identification protocols [47], whilst another intervention used monthly prescribing rate feedback to establish continuous self-monitoring loops through trend visualisation and comparative performance data [45].

soziale Einflüsse (17 Nudges)

Social influences were addressed through 17 nudges. These interventions systematically leveraged peer comparison dynamics, implementing percentile-based ranking systems and regional performance benchmarking to activate competitive professional behaviours. One intervention [50] utilised individualised peer comparison reports and national distribution visualisation to create salient social comparison points, while another [33] employed a monthly email-based peer ranking system to establish ongoing social accountability mechanisms through transparent performance disclosure.

Ziele (16 Nudges)

Goals were addressed through 16 nudges. These interventions systematically established clear performance targets and facilitated behavioural self-monitoring to enhance physicians' capacity for goal-directed prescribing behaviour. Several interventions utilised peer comparison feedback mechanisms that enabled physicians to assess their performance against explicit benchmarks, creating opportunities for goal setting and progress tracking [43, 46, 50]. One intervention [50] combined individualised peer comparison reports with national distribution visualisation to establish concrete performance standards, while another [46] employed audit feedback with specific performance metrics to support physicians in identifying discrepancies between current and desired prescribing patterns.

kognitive Domänen (10 Nudges)

Memory, attention, and decision processes, as observed in ten nudges, represent the primary cognitive pathway for intervention delivery. These interventions predominantly utilised CDST integrated into EHR, implementing real-time algorithms that modify decision architecture at the point of care. For example, one algorithm exemplifies this approach through automated risk stratification using predictive modelling [41], whilst another intervention demonstrates cognitive load reduction via streamlined ordering pathways embedded within EHR-integrated guideline prompts [43].

Annahme von Konsequenzen (10 Nudges)

Beliefs about consequences were covered through ten nudges. These interventions focused on altering clinicians' cognitive representations of prescribing outcomes through mandatory justification protocols and evidence-based risk communication. In one nudge [43], the EHR-integrated accountability system, which requires written prescribing rationales, demonstrates direct consequence salience enhancement. In another nudge [41] case-mix-adjusted performance data combined with harm probability messaging illustrate evidence-based belief modification strategies.

weitere Faktoren: Wissen, Verstärkung, Fähigkeiten, Intentionen und Umweltkontext und Ressourcen

Additional behavioural change factors were employed less frequently across the interventions: *knowledge* was addressed in eight nudges, *reinforcement* in six nudges, *skills* and *intentions* in three nudges each, and *environmental context and resources* in two nudges.

3. Behavioural drivers

MINDSPACE-Treiber: strategische Kombinationen zur Verhaltensbeeinflussung

The interventions employed multiple drivers from the MINDSPACE framework in strategic combinations to influence prescribing behaviour through various psychological mechanisms (see Table 3-2 for the categorisation of identified nudges). The drivers were:

Ego (21 Nudges) und …

Ego emerges as the most prominent driver, which could be attributed to 21 nudges representing nearly every intervention. Ego is consistently implemented through peer comparison systems [43, 46, 49], individualised feedback reports [42, 44, 46, 50, 51], and accountable justification [43, 45], which appeal to professional identity and competence.

… Affekt-Mechanismen (21 Nudges) als dominante Treiber

Affect is extensively utilised in 21 nudges, through visual pop-ups [41, 43, 45, 48] or performance indicators [43, 45, 46, 49, 50], emotionally engaging feedback mechanisms [43, 44, 46, 47], and infographics highlighting medication harms [44, 51].

… Messenger-Effekte (15 Nudges)

Messengers are featured in 15 nudges, prominently across interventions where credibility and authority are crucial. This includes co-signed letters from professional organisations [49, 50], feedback delivered by respected clinical authorities such as HIRs [43, 44, 46, 51], and content narrated by practising clinicians or experts [47].

… Priming (12 Nudges)

Priming appears in twelve nudges. This driver is consistently implemented through CDST [41, 42, 45, 48], which activate contextual cues, alert mechanisms that prime specific decision pathways [33, 35, 37], and feedback systems that enhance awareness of prescribing patterns [46, 50]. The priming effect is particularly evident in EHR-based interventions that automatically trigger when specific diagnoses are entered [41, 43, 45] or when prescribing thresholds are exceeded [46].

… Normen (9 Nudges)

Norms are attributed to eleven nudges. These are frequently used in peer comparison interventions [42, 43, 45, 46, 49, 50], establishing social benchmarks and professional standards through comparative prescribing data, ranking systems, and regional/national prescribing rate comparisons. These interventions leverage social proof by positioning appropriate prescribing as the professional standard.

… Salienz-Mechanismen (10 Nudges)

Salience is utilised in ten nudges, primarily through attention-capturing mechanisms such as pop-up alerts [41, 45, 48], visual performance indicators [50], and prominent risk assessment displays [48].

… Default-Optionen (4 Nudges)

Defaults were implemented in four nudges, primarily through electronic decision support systems that pre-populated antibiotic prescriptions with guideline-concordant alternatives [41, 42, 44, 48], thereby redirecting prescribing behaviour at the point of clinical decision-making.

… Anreize (1 Nudge)

Incentives appeared in only one nudge, incorporated as part of a multicomponent intervention combining suggested alternatives, accountable justification, and peer comparison feedback [43].

Table 3-2: Identified nudges and their categorisation

Study	Intervention (Nudge)	Nudge clustered according to …		
		Intensity level	Behavioural change factors	Behavioural drivers
Antibiotics				
Blair, 2023 [41]	Chico intervention	⇧	Memory, attention and decision processes; Social Influences; Environmental context and resources; Emotion	Defaults; Ego; Affect; Priming, Salience
Gulliford, 2019 [42]	Multicomponent intervention	⇧	Memory, attention and decision processes; Knowledge; Social influences; Environmental context and resources; Skills; Emotion; Beliefs about consequences	Defaults; Norms; Priming; Salience; Ego
Meeker, 2016 [43]	Suggested alternatives	⇔	Memory, attention and decision Processes; Intentions, Emotion	Salience, Priming, Affect
	Accountable justification	⇔	Beliefs about consequences, Emotion	Norms, Ego, Affect
	Peer comparison	⇩	Social influences; Emotion; Goals; Behavioural regulation	Messenger, Affect, Ego
	Suggested Alternatives + Peer Comparison	⇔	Memory, attention and decision processes; Social influences; Emotion; Goals; Behavioural regulation; Intentions	Salience, Priming, Messenger, Affect, Ego
	Accountable Justification + Peer Comparison	⇔	Beliefs about consequences; Social influences; Emotion; Goals; Behavioural regulation	Messenger, Norms, Ego, Affect
	Suggested Alternatives + Accountable Justification + Peer Comparison	⇔	Beliefs about consequences; Social influences; Emotion; Goals; Behavioural regulation; Memory, attention and decision processes, Intentions	Salience, Priming, Messenger, Affect, Ego, Incentives, Norms
Jeanmougin, 2024 [44]	Feedback Visit	⇩	Social influences; Beliefs about consequences; Reinforcement; Knowledge; Emotion; Behavioural regulation	Messenger, Ego, Affect
	Electronic decision support tool	⇧	Social influences; Reinforcement; Memory, attention and decision processes; Goals; Emotion; Behavioural regulation	Defaults, Affect, Ego
Schwartz, 2024 [51]	Mailed letter[8]	⇩	Behavioural regulation; Social influences; Emotion; Goals; Knowledge	Messenger, Ego, Affect; Norms, Priming, Salience
Opioids				
Dun, 2023 [50]	Individualised peer comparison report	⇩	Social influences; Reinforcement; Memory, attention and decision processes; Goals; Emotion; Behavioural regulation	Messenger, Affect, Ego, Norms, Priming, Salience
Kreamer, 2022 [45]	Alert+ justification	⇔	Memory, attention and decision processes; Skills, Emotion, Beliefs about consequences	Priming, Salience, Ego, Affect
	Peer Comparison group	⇩	Social influences; Emotion; Goals; Behavioural regulation; Knowledge	Messenger, Norms, Ego, Affect
	All interventions combined	⇔	Memory, attention and decision processes; Skills; Beliefs about consequences; Social influences; Emotion; Goals; Behavioural regulation, Knowledge	Messenger, Norms, Ego, Affect, Salience, Priming,
Navathe, 2022 [46]	Individual audit feedback	⇩	Beliefs about consequences; Emotion; Reinforcement; Goals; Behavioural regulation	Messenger, Affect, Ego, Priming
	Peer comparison feedback	⇩	Social influences; Emotion; Goals; Behavioural regulation	Messenger, Affect, Ego, Affect
	Individual audit + peer comparison feedback	⇩	Beliefs about consequences; Emotion; Reinforcement; Goals; Behavioural regulation; Social influences	Messenger, Affect, Ego, Norms, Priming

[8] Following Schwartz et al.'s (2024) [51]analytical approach, which combined the four intervention groups (case-mix adjusted feedback, unadjusted feedback, harms messaging and non-harms messaging) for comparison against control, we similarly report these as a single nudge intervention in our results.

Study	Intervention (Nudge)	Nudge clustered according to …		
		Intensity level	Behavioural change factors	Behavioural drivers
Other medication				
Presseau, 2018 [47]	Behavioural change-focused outreach intervention	⇩	Social influences; Reinforcement; Goals; Emotion; Behavioural regulation; Knowledge	Messenger, Ego, Affect
Rieckert, 2020 [48]	Electronic decision support tool	⇧	Memory, attention and decision processes; Goals; Emotion; Behavioural regulation; Beliefs about consequences	Defaults; Affect; Ego; Priming, Salience
Guthrie, 2016 [49]	Educational newsletter + peer comparison feedback	⇩	Social influences; Emotion; Goals; Behavioural regulation; Knowledge	Messenger; Norms; Ego; Affect
	Educational newsletter + peer comparison feedback and one-page theory-informed behavioural change component	⇩	Social influences; Emotion; Goals; Behavioural regulation; Knowledge	Messenger; Norms; Ego; Affect

Abbreviations: EHR … electronic health records; GP … general practitioner; HIR … health insurance representative
Legend: ⇩ low-level, ⇔ mid-level, ⇧ high-level.

3.2 Effectiveness, safety, and economic and implementation aspects of identified nudges (RQ 2)

Relevant Outcomes

The following section defines the outcomes relevant to this research question:

relevante Ergebnisse für FF2

- Effectiveness outcomes

  Effektivität:

  - *Total prescribing* refers to the aggregate measurement of all prescriptions within a specific medication category, providing a comprehensive view of overall prescribing behaviour rather than focusing on particular subsets or specific types of medications.

    Gesamtverschreibungsverhalten

  - *Specific prescribing* refers to targeted measurements that focus on particular subsets, types, or characteristics of prescriptions within a medication category, rather than looking at all prescriptions collectively.

    spezifische Verschreibungen

- Safety outcomes

  Sicherheit:

  - *Hospitalisation/rate of return visits* serves as an essential safety indicator, helping determine whether changes in prescribing behaviour inadvertently compromise patient care or outcomes.

    Hospitalisierung/ Rückkehrrate

  - *Harms* are specifically measured through serious adverse events (SAEs), track whether changes in prescribing behaviour lead to significant patient harm or safety incidents.

    Schäden

- Economic outcomes

  ökonomische Ergebnisse:

  - *Prescription costs* measure the financial impact of prescribing interventions, tracking changes in medication expenditure following implementation. This includes direct drug costs, administration expenses, and overall pharmaceutical spending per patient or per population.

    Verschreibungskosten

  - *Service use costs* include all costs that are not connected to prescription costs.

    Dienstleistungskosten

- Implementation outcomes
  - *Costs of intervention* measure the direct expenses associated with implementing and maintaining the prescribing intervention itself. This includes staff time for training and delivery, technology development and maintenance costs, administrative expenses, materials and resources, and ongoing monitoring systems.
  - *Use of intervention* measures how extensively and consistently the prescribing intervention is actually utilised by clinicians in practice. This includes metrics such as system login rates, engagement with clinical decision support tools (CDSTs), response rates to feedback reports, participation in educational components, and overall adherence to the intervention protocol.
  - *Feedback from practitioners* captures clinicians' perspectives, experiences, and satisfaction with prescribing interventions through surveys, interviews, or feedback forms. This includes their perceptions of the intervention's usefulness, ease of implementation, impact on workflow, acceptability, and suggestions for improvement.

Implementierungsergebnisse:

Interventionskosten

Verwendung der Intervention

Rückmeldung der Ärzt:innen

The study characteristics and extracted results of the included studies are displayed in the Appendix in Table A-6 to Table A-8 and in the risk of bias profiles in Table A-10 to Table A-15. Results were structured by medication category (antibiotics, opioids, other medications) to facilitate comparison and identify potential variations in nudge effectiveness across different medication types.

kategorienspezifische Ergebnisdarstellung

3.2.1 Antibiotics

A total of five studies [41-44, 51] examined eleven nudging interventions to optimise antibiotic prescribing. All studies included data on effectiveness outcomes; three [41-43] reported on safety outcomes, and two [41, 42] reported on economic and implementation outcomes. The studies were conducted across multiple healthcare systems, including two in the UK [41, 42], one each in the USA [43], France [44], and Canada [51]. All interventions were implemented in primary care settings, specifically general practitioner practices. Study scales varied considerably, ranging from 47 medical practices in the smallest study to over 5,000 physicians in the largest [51]. One study included 336,496 patients [41], while another reported data from 16,959 patient visits [44]. Four studies were cluster RCTs [41-44] and one was an individually randomised RCT [51], with study durations ranging from twelve to 18 months.

Antibiotika: 5 RCTs mit 11 Nudges

Primärversorgung in UK, USA, Frankreich und Kanada

Studiendauer: 12-18 Monate

The outcomes were assessed as having a low to high risk of bias. Concerns were raised primarily regarding the aspects of 'bias due to deviations from intended interventions', 'bias in measurement of the outcome' and 'bias in selection of the reported result' (see Table A-10 and Table A-11 in the Appendix for more information).

RoB: niedrig bis hoch

Effectiveness

A summary of nudges that demonstrated a statistically significant effect compared to the control group is presented in Table 3-3. Overall, six nudges (three low, one mid, two high-level) demonstrated a significant effect compared to the control group, mostly reflected in antibiotic prescribing rates.

6 Nudges mit statistisch (stat.) signifikanten (sig.) Effekten vs. Kontrollgruppen (KG)

Table 3-3: Summary table of nudge interventions that improved antibiotic prescribing compared to control

Nudge	Level	Effective in improving:
CDST + visits from HIR	⇧	Mean and different critical antibiotic prescriptions
Multicomponent intervention	⇧	Antibiotic prescriptions for RTIs
Accountable justification	⇔	Antibiotic prescribing rate
Mailed letter	⇩	Mean antibiotic prescribing rate per 1,000 patient visits, broad-spectrum antibiotic prescribing, and unnecessary prescribing.
Peer comparison	⇩	Antibiotic prescribing rates
Feedback visits	⇩	Different critical antibiotics

Abbreviations: CDST … clinical decision support tool; HIR … health insurance representative; RTI … respiratory tract infection

The following section presents all effectiveness outcomes reported in the included studies, including both effective and non-effective interventions.

wirksame und unwirksame Nudges

Total prescribing

Low-level interventions vs. control

One study found that educational feedback visits had no statistically significant impact, failing to reduce prescribing rates compared with controls [44]. However, two interventions of two other studies [43, 51] demonstrated significant effectiveness. The mailed letter intervention (a combination of the four interventions, case-mix adjusted feedback, unadjusted feedback, harms messaging and non-harms messaging) [51] showed a lower mean antibiotic prescribing rate per 1,000 patient visits at 6-months [56.0, standard deviation (SD): 39.2] vs 59.4 (SD: 42.0); relative rate (RR): 0.95 (95% confidence interval (CI): 0.94 to 0.96)] and at twelve months [63.7 vs. 66.9; RR: 0.96 (95% CI: 0.95 to 0.97)] follow-up compared to the control group. Peer comparison feedback [43] reduced antibiotic prescriptions by 5.2% compared to the control group and from 19.9% before to 3.7% after the intervention (absolute difference: -16.3%; difference-in-differences: -5.2% [95% CI: -6.9% to -1.6%]; $p < .001$).

3 ⇩ Nudges, 2 stat. sig. vs. KG:

***Briefintervention* und *Peer-Vergleich-Feedback* reduzieren Antibiotika-verschreibungen**

Mid-level interventions vs. control

One study [43] demonstrated partly statistically significant reductions in antibiotic prescribing rates from baseline to 18 months in two mid-level interventions. Compared with the control group, the accountable justification intervention reduced prescriptions by an additional 7% (difference in differences, -7.0% [95% CI: -9.1% to -2.9%]; $p < .001$; pre vs. post intervention: 23.2% to 5.2%, absolute difference: -18.1%) Suggested alternatives showed no statistically significant effect compared to the control (difference in differences, -5.0% [95% CI: -7.8% to 0.1%]; $p = .66$), however it reduced prescribing rates from 22.1% pre to 6.1% post intervention (absolute difference: -16.0%).

2 ⇔ Nudges, 1 stat. sig. vs. KG:

***Verschreibungs-begründungspflicht* reduziert Verschreibungsrate**

High-level interventions vs. control

Two studies found no evidence of a reduction in antibiotic prescription for two high-level interventions compared to their control groups [41, 42]. However, in one study [44], the mean volume of systemic antibiotics per GP decreased by 219.2 (SD: 61.4; 95% CI -339.5 to -98.8; $p < .001$) defined daily doses at twelve months follow-up in the intervention group with a CDST and control visits compared to the control group, which had no intervention.

3 ⇧ Nudges, 1 stat. sign. vs. KG; *CSDT* mit weniger Tagesdosen-verschreibungen pro Hausarzt/Hausärztin

Specific prescribing

Low-level interventions vs. control

One study [51] demonstrated significantly lower antibiotic prescribing rates per 1,000 patient visits in the pooled mailed letter group compared to controls after six-month and twelve months of follow-up across three measures: broad-spectrum antibiotics (six-months: 26.0 vs. 28.4; RR: 0.94, 95% CI: 0.92 to 0.95; twelve-months: 31.6 vs. 34.0, RR: 0.95, 95% CI: 0.94 to 0.96), likely unnecessary prescriptions [six months: 7.5 vs. 8.6, RR: 0.89 (95% CI: 0.86 to 0.92); twelve-months: 10.3 vs. 11.4, RR: 0.92, 95% CI (0.91 to 0.94)], and long-duration prescriptions [six-months: 13.7 vs. 16.5, RR: 0.85 (95% CI: 0.83 to 0.87); 15.0 vs. 17.8, RR: 0.86 (95% CI: 0.91 vs. 0.94)]. Another study [44] demonstrated significant reductions in the feedback visit intervention group compared to control after twelve months of follow-up for critical antibiotics [mean difference (MD): -101.3, 95% CI: -148.1 to -54.5; $p<.001$], cephalosporins (MD: -24.2, 95% CI: -37.8 to -10.7; $p=.001$), quinolones (MD: -15.9, 95% CI: -28.0 to -3.7; $p=.011$), and amoxicillin-clavulanic acid (MD: -63.3, 95% CI: -98.6 to -28.0; $p<.001$).

2 ⇩ Nudges, beide stat. sign. vs. KG:

***Briefintervention* reduziert Breitspektrum-Antibiotika, unnötige und Langzeit-Verschreibungen**

***Feedback-Besuche* reduzieren kritische Antibiotika**

Mid-level intervention vs. control

One study [43] found no evidence of a reduction in inappropriate antibiotic prescriptions for any mid-level intervention group.

0/2 ⇔ Nudges stat. sig. vs. KG

High-level intervention vs. control

One study with a multicomponent intervention [42] demonstrated a statistically significant effect, with the intervention group having fewer antibiotic prescriptions for respiratory tract infections (RTIs) compared to controls (98.7 vs. 107.6 per 1000 patient-years; unadjusted RR 0.92; adjusted rate ratio 0.88 [95% CI: 0.78 to 0.99; $p=0.040$]). For antibiotic prescribing for RTI in adults aged 15-84 years, the absolute risk reduction was -16.0 (95% CI: 5.0 to -25.1), with one antibiotic prescription avoided for every 62 (95% CI: 40 to 200) registered patients aged 15-84 years per year. No evidence of effect was found in children aged <15 years or adults aged ≥85 years. Furthermore another study demonstrated significant reductions in antibiotic prescribing in the CSDT visit intervention group [44] compared to control group after twelve months of follow-up for critical antibiotics (MD: -96.2, 95% CI: -143.2 to -49.2; $p<.001$), cephalosporins (MD: -19.8, 95% CI: -33.4 to -6.2; $p=.005$), and amoxicillin-clavulanic acid (MD: -64.0, 95% CI: -99.4 to -28.5; $p<.001$), as well as for the volume of prescriptions in patients aged <65 years (MD: -42.1, 95% CI: -83.0 to -1.2; $p=.044$) and under six years (MD: -20.0, 95% CI: -31.4 to -8.5; $p=.001$).

2 ⇧ Nudges, beide stat. sig. vs. KG:

***Multikomponenten-Interventionen* reduzieren Verschreibungen bei Atemwegsinfektionen**

***CSDT-Besuch-Intervention* reduziert Verschreibungen von kritischen Antibiotika**

Safety

A summary of the safety outcomes is presented in Table 3-4.

Table 3-4: Summary of safety outcomes related to antibiotic prescribing nudges compared to control

Nudge	Level	Safety
CDSTs	⇧	Non-inferiority compared to controls in terms of hospitalisation rates; No evidence that twelve safety outcomes might be increased as a result of the intervention
Multicomponent intervention	⇧	No difference to usual care for safety outcomes
Suggested alternatives	⇔	No difference to usual care for safety outcomes

Nudge	Level	Safety
Accountable justification	⇔	No difference to usual care for safety outcomes
Accountable justification + peer comparison	⇔	Higher rate of return visits for possible bacterial infections within 30 days following visits for acute RTI in which antibiotics were not initially prescribed
Accountable justification + peer comparison + suggested alternatives	⇔	Higher rate of return visits compared to the control

Abbreviations: HIR … health insurance representative; RTI … respiratory tract infection

Rate of return visits/hospitalisation

Mid-level vs. control

One study [43] demonstrated that the accountable justification plus peer comparison intervention resulted in a statistically significantly higher rate of return visits for possible bacterial infections within 30 days following visits for acute RTI (both antibiotic-inappropriate and potentially antibiotic-appropriate) in which antibiotics were not initially prescribed. The combined intervention group had a return visit rate of 1.41% (95% CI: 1.06% to 1.85%) compared to 0.43% (95% CI: 0.25% to 0.70%) in the control group.

1 ⇔ Nudge stat. sig. vs. KG: *Verschreibungsbegründung* mit erhöhter Wiederbesuchsrate bei nicht antibiotisch behandelten ARIs

High-level vs. control

One study [41] showed the non-inferiority of the CDST intervention compared to the control group in terms of hospitalisation rates. The intervention group had a hospitalisation rate of 0.019 (95% CI: 0.014 to 0.026) versus 0.021 (95% CI: 0.014 to 0.029) in the control group (RR: 0.952; 95% CI: 0.905 to 1.003).

1 ⇧ Nudge nicht stat. sig. vs. KG

Harms

High-level vs. control

One study [41] reported four serious adverse events, including three fatalities (one in the control group and two in the intervention group, both unrelated to the intervention) and one hospitalisation in the intervention group. Another study found no evidence that twelve safety outcomes, including pneumonia and peritonsillar abscess, were increased as a result of the intervention.

2 ⇧ Nudges nicht stat. sig. vs. KG

Economic outcomes

Prescription costs

High-level vs. control

One study [41] found no evidence of a between-arm difference in costs when comparing the dispensed amoxicillin and macrolides between the intervention and control groups.

1 ⇧ Nudge nicht stat. sig. vs. KG

Service use costs

High-level vs. control

One study [41] conducted an economic evaluation and found no statistically significant difference in mean National Health Service (NHS) costs between the study arms, with a mean difference of -£1,999 (95% CI: -£6,627 to 2,630). Another study [42] found no evidence that the total costs of healthcare utilisation differed as a result of the intervention, at least during the trial's time horizon.

2 ⇧ Nudges nicht stat. sig. vs. KG

Implementation outcomes

Costs of intervention

High-level intervention vs. control

One study [41] estimated the costs of the intervention as £210 per medical practice, which comprised non-research-related costs incurred at the practice level, including those associated with integrating the intervention into local computers and training costs borne by the practice.

1 ⇧ Nudge: *CDST*-Implementierungskosten pro Praxis von £210

Use of intervention

High-level intervention vs. control

One study [41] reported a median usage of 70 uses [interquartile range (IQR): 9-142] across medical practices at twelve months follow-up among 115 medical practices. Another study [42] examined utilisation of CDSTs for RTI consultations, which ranged from less than 1% in the lowest quartile to up to 28% in the highest quartile.

2 ⇧ Nudges: *CDST*-Nutzung variiert erheblich zwischen Praxen

Feedback from practitioners

High-level intervention vs. control

A qualitative evaluation of one study [41] found that clinicians appreciated the intervention and utilised it as a supportive aid, particularly with borderline cases. However, it did not always integrate well within the consultation flow and was used less over time. Another study's [42] process evaluation questionnaire received responses from 51 respondents across 31 out of 41 (76%) intervention trial arm medical practices. Respondents provided positive feedback on monthly antibiotic prescribing reports, finding them credible, easy to understand, useful for discussions with colleagues, and beneficial for practice. However, fewer respondents (<80%) agreed that the reports encouraged reduced prescribing or impacted practice prescribing. The webinar was well-received. Decision support tools were less favourably received than prescribing reports, with nearly one-third not affirming that the tools would support reduced antibiotic prescribing.

2 ⇧ Nudges: qualitative Evaluation zeigt Diskrepanz zwischen Tool-Wertschätzung und Verhaltensänderung von *CDST*

3.2.2 Opioids

A total of three studies [45, 46, 50] examined seven nudging interventions to optimise opioid prescribing. All three studies could be used to assess effectiveness, but none reported on safety, economic, or implementation outcomes. All studies were conducted in the USA healthcare system. The interventions were implemented across different healthcare settings: one in secondary care targeting outlier surgeons [50], one in primary care clinics [45], and one in emergency departments and urgent care facilities in secondary care [46]. Study scales varied considerably, ranging from 48 clinics in the smallest study [45] to 489 individual surgeons in the largest [50], with one study involving 438 clinicians across 48 facilities [46]. Patient populations ranged from a median of 14 patients per surgeon [50] to 294,962 patients [46]. Two studies were cluster RCTs [45, 46], and one was an individual RCT [50], with study durations ranging from twelve to 18 months.

Opioide: 3 US-Studien mit 7 Nudges

keine Daten zu Sicherheit, Ökonomie und Implementierung

Studiendauer: 12-18 Monate

The risk of bias (RoB) for the outcomes of the included RCTs was assessed as low to high. Concerns were raised primarily regarding the aspects of 'Bias arising from the randomisation process' and 'bias due to missing outcome data' (see Table A-12 and Table A-13 in the Appendix for more details).

RoB: niedrig bis hoch

Effectiveness

A summary of nudges that demonstrated a statistically significant effect compared to the control group is presented in Table 3-5. Overall, three low-level nudges demonstrated a significant effect compared to the control group, mostly expressed in terms of opioid prescribing rates.

3 ⇩ Nudges mit stat. sig. Effekten vs. KG

Table 3-5: Summary table of nudge interventions that improved opioid prescribing compared to control

Nudge	Level	Effective for prescriptions of
Individualised peer comparison report	⇩	Mean opioid tablet prescribing
Peer comparison	⇩	■ Prolonged opioid prescription of more than three months; ■ Concurrent opioid/benzodiazepine prescriptions; ■ New opioid prescriptions; ■ Opioid prescribing at the index visit
Individual audit feedback + peer comparison feedback	⇩	Opioid pills per prescription

The following section presents all effectiveness outcomes reported in the included studies, including both effective and non-effective interventions.

wirksame und unwirksame Nudges

Total prescribing

Low-level intervention vs. control

One study [46] showed significant reductions in pills per prescription during the intervention period for peer comparison feedback (-0.8 pills; 95% CI: -1.4 to -0.3; $p=.003$) and a combined intervention (individual audit feedback + peer comparison feedback: -1.2 pills; 95% CI: -1.8 to -0.7; -1.2). During the follow-up period, both peer comparison feedback (-1.0 pills; 95% CI: -1.8 to -0.3; $p=.007$) and combined interventions (-1.1 pills; 95% CI: -1.9 to -0.3; $p=.008$) maintained significant reductions compared to the control group. Another study [50] showed significant reduction in mean tablet prescribing in the individualised peer comparison report-group with 10.54 (SD: 5.34) versus 12.30 (SD: 6.02) in the control group ($p=.04$). Multivariable linear regression analysis confirmed that patients in the intervention group received 1.83 fewer opioid tablets per patient (95% CI: -3.61 to -0.04; $p=.04$). In the intervention group, prescribing decreased by a mean of 9.45 units ($p<.001$), with 97.7% of surgeons (85/87) reducing their prescribing patterns. The control group also demonstrated a significant reduction of 9.27 units ($p<.001$).

3 ⇩ Nudges, alle stat. sig. vs. KG:

***Peer-Vergleich, individuelles Audit-Feedback + Peer-Vergleich* und *individueller Peer-Vergleichsbericht* reduzieren Pillenverschreibung**

Mid-level intervention vs. control

One study [45] reported a 3.6% reduction in opioid prescriptions in the alert group, and a decrease of 1.9% in the alert + peer comparison group pre versus post-intervention; however, no between-group comparisons were reported for this study.

2 ⇔ Nudges ohne Gruppenvergleiche

Specific prescribing

Low-level intervention vs. control

One study [45] demonstrated that peer comparison feedback achieved significant reductions in prolonged opioid prescribing of more than three months [adjusted Odds Ratio (aOR): 0.79; 95% CI: 0.69-0.91; $p=.001$], concurrent opioid/benzodiazepine prescriptions (aOR: 0.85; 95% CI: 0.72 to 1.00; $p=.04$), and new opioid prescriptions (aOR: 0.60; 95% CI: 0.38 to 0.96; $p=.03$) compared to controls. Opioid prescribing at the index visit was lower in the pooled comparison (main effects) model (aOR: 0.60; 95% CI: 0.38 to 0.96) throughout the total intervention period and after the comparison emails were sent.

1 ⇩ Nudge stat. sig. vs. KG:

***Peer-Vergleich-Feedback*, reduziert Langzeit-, Opioid-Benzodiazepin-Ko- und neue Verschreibungen**

Mid-level intervention vs. control

One study [45] found no significant effect of an alert with a guideline checklist requiring justification on new opioid prescriptions (adjusted odds ratio, aOR: 0.74; 95% CI: 0.46 to 1.18; $p=.20$).

1 ⇔ Nudge nicht stat. sig. vs. KG

3.2.3 Other medications

A total of three studies [47-49] examined four nudging interventions to optimise prescribing practices across different therapeutic areas. All three studies could be used to assess effectiveness, with one each also reporting on safety [48] and economic [47] outcomes, but implementation outcomes were not reported. Two studies were conducted within the UK healthcare system [47, 49], and one was conducted across multiple European countries [48]. The interventions were implemented exclusively in primary care settings, targeting behaviour change for blood pressure and glycemic control [47][9], comprehensive medication review for deprescribing in older adults [48], and educational approaches to reduce high-risk prescribing [49]. Study scales varied considerably, from 44 medical practices in the smallest study [47] to 359 medical practices in the largest [48]. Only one study reported a patient population, which was 3,904 [48]. All three studies were cluster RCTs, with study durations ranging from twelve to 24 months.

sonstige Medikamente: 3 Studien mit 4 Nudges

Studien aus Europa zu Diabetes-Management, Deprescribing und Hochrisiko-Verschreibung

44-359 Praxen

Studiendauer: 12-24 Monate

The RoB for the outcomes of the included RCTs was assessed to be low (see Table A-14 and Table A-15 in the Appendix for more details).

RoB: niedrig

Effectiveness

A summary of nudges that demonstrated a statistically significant effect compared to the control group is presented in Table 3-6. Overall, two low-level nudges and one high-level nudge demonstrated a significant effect compared to the control group, mostly expressed in terms of high-risk prescribing.

1 ⇧ und 2 ⇩ Nudges mit stat. sig. Effekten vs. KG

[9] This study targeted the improvement of type 2 diabetes management in primary care including outcomes on glucose-lowering and antihypertensive medication prescribing, foot examinations, and patient education. For the present review, only prescribing outcomes for insulin and antihypertensive medications were extracted and analysed.

Table 3-6: Summary table of nudge interventions that improved other medication prescribing compared to control

Nudge	Level	Effective for prescriptions of
CDST	⇧	Number of prescribed drugs
Educational newsletter + feedback	⇩	Reduction of high-risk prescribing
Educational newsletter + feedback + behavioural change component	⇩	Reduction of high-risk prescribing

Abbreviation: CDST …clinical decision support tool

The following section presents all effectiveness outcomes reported in the included studies, including both effective and non-effective interventions.

wirksame und unwirksame Nudges

Total prescribing

High level vs. control

One study [48] demonstrated that an electronic CDST comprising a comprehensive drug review significantly reduced the number of prescribed drugs in the intervention group compared to the control group at 24-month follow-up [incidence rate ratio (IRR): 0.95; 95% CI, 0.94 to 0.97; $p<.001$]. Sensitivity analysis supported this finding.

1 ⇧ Nudge stat. sig. vs. KG: *CDST* reduziert Medikamenten-verschreibungen

Specific prescribing

Low-level vs. control

Two studies examined three low-level nudges for specific prescribing of other medications. One study [47] showed no statistically significant differences between the behaviour change outreach intervention and controls at 12-month follow-up for insulin initiation [IRR: 1.18; 95% CI: 0.95 to 1.48; $p=.13$] or blood pressure medication (IRR: 1.05; 95% CI: 0.96 to 1.16; $p=.29$). Another study [49] demonstrated significant reductions in high-risk prescribing for antipsychotics, non-steroidal anti-inflammatories, and antiplatelets at the end of the intervention period for both educational newsletter plus feedback (aOR 0.88; 95% CI: 0.80 to 0.96; $p=.007$) and educational newsletter plus feedback with theory-informed behavioural change component (aOR: 0.86; 95% CI: 0.78 to 0.95; $p=.002$) compared to controls. The educational newsletter plus feedback group showed no immediate level change but demonstrated a statistically significant slope change toward steeper reduction (OR: per year 0.87; 95% CI: 0.83-0.92), whilst the theory-informed intervention group exhibited both immediate reduction in high-risk prescribing level (OR: 0.96; 95% CI: 0.93 to 1.00) and significant slope change toward steeper reduction (OR: per year 0.88; 95% CI: 0.84 to 0.93).

3 ⇩ Nudges, 2 stat. sig. vs. KG

***Bildungs-Newsletter + Feedback* und *Bildungs-Newsletter + Feedback + theoriegestützte Komponente zur Verhaltensänderung* reduzieren Hochrisiko-Verschreibungen**

Safety

A summary of the safety outcomes is presented in Table 3-7.

Table 3-7: Summary of safety outcomes from other medication prescribing nudges

Nudge	Level	Safety
CDST	⇧	non-significant reduction of unplanned hospital admissions or death

Abbreviations: CDST … clinical decision support tool

Rate of return visits/hospitalisation

High-level vs. control

One study [48] examined the composite outcome of unplanned hospital admission or death by 24 months, comparing the intervention group versus the control group. The intervention group had 871 events (44.6%) compared to 944 events (48.4%) in the control group. Intention-to-treat analysis revealed an odds ratio of 0.88 (95% CI: 0.73-1.07; $p=.19$), indicating a non-significant reduction in the composite outcome (997 of 1,953 intervention patients vs. 1,055 of 1,951 control patients).

1 ⇧ Nudge nicht stat. sig. vs. KG

Economic outcomes

Prescription costs

Low-level intervention vs. control

One study [47] examined per-patient prescription costs for injectable medication to manage glycaemic control, comparing baseline versus post-intervention periods. Post-intervention log-transformed costs per patient did not differ significantly between groups ($p=.25$). The intervention group costs were £6,531 (95% CI: £6,237 to £6,824) at baseline versus £6,081 (95% CI: £5,806 to £6,357) post-intervention, while the control group costs were £7205 (95% CI: £6,911 to £7,499) at baseline versus £6570 (95% CI: £6,313 to £6,827) post-intervention. No between-group differences were available for blood pressure prescription costs. The intervention group had costs of £96 (95% CI: £92 to £99) at baseline versus £92 (95% CI: £89 to £96) post-intervention, while the control group had costs of £89 (95% CI: £83 to £94) at baseline versus £84 (95% CI: £78 to £88) post-intervention.

1 ⇩ Nudge nicht stat. sig. vs. KG

Service use costs

Low-level intervention vs. control

One study[10] [47] found higher costs comparing intervention (behaviour change via outreach visits) versus control group: mean of £24.46 per patient (95% CI: £23.90 to £25.03) in the intervention group versus £21.61 per patient (95% CI: £20.92 to £22.31) in the control group ($p<.001$).

1 ⇩ Nudge stat. sig. vs. KG: *Bildungsbesuche* erhöhen Gesamtkosten pro Pat.

Implementation outcomes

Costs of intervention

Low-level intervention vs. control

One study [47] estimated the cost of intervention development and delivery for the research team at £1,191 per medical practice.

1 ⇩ Nudge mit £ 1,191 Implementierungskosten pro Praxis

[10] This study aimed to improve type 2 diabetes management in primary care across multiple outcomes, including glucose-lowering and antihypertensive medication prescribing, foot examinations, and patient education; therefore, the costs encompass more than prescribing alone.

Use of intervention

High-level vs. control

One study [48] found that doctors in the intervention group created 18.7 (SD: 8.8) datasets for each participant throughout the study, whereas doctors in the control group created only 12.1 (SD: 5.1) datasets.

1 ⇧ Nudge: *CDST* mit mehr Pat.-Einträgen vs. KG

3.3 Implementation feasibility of nudging interventions in the Austrian healthcare system (RQ3)

To answer this research question, the responses from three experts to the questionnaire developed for this purpose (see Appendix Table A-16) are summarised. The expert consultation examined five main nudging intervention categories, which proved effective in addressing the RQ2: peer comparison, prescribing justification, CDSTs, educational interventions and multicomponent interventions[11].

Expert:innenkonsultation zur Implementierbarkeit von 5 Nudging-Ansätzen

Implementation feasibility by intervention type

Regarding **peer comparison** interventions, the survey responses show a mixed implementation status within Austria, with some comparative elements already in place through established healthcare insurance mechanisms. However, significant barriers emerge around physician workload concerns, with respondents consistently citing excessive personnel and time expenditure ("zu hoher Personal- und Zeitaufwand") as a primary obstacle. Despite these reservations, respondents acknowledged the existing infrastructure through the Austrian Health Insurance Fund (*Österreichische Gesundheitskasse*, ÖGK) system, which could support such interventions, provided they are framed constructively rather than punitively. Acceptance levels remain cautious, with emphasis on ensuring fair and contextually appropriate comparisons that respect professional autonomy.

Peer-Vergleich in Österreich teilweise etabliert

Personal- und Zeitaufwand als Hauptbarriere

Mandatory **prescribing justification** represents the most mature intervention category, with respondents noting substantial existing implementation through the Medical Prescription Law (*Ärzteverordnungsgesetz*) [52]. This legal framework already requires comprehensive documentation of prescribing decisions, creating a foundation for nudging interventions to build on. The minimal implementation barriers and high acceptance levels for this intervention type reflect its alignment with established professional obligations and existing documentation practices within Austrian healthcare.

Verschreibungsbegründung bereits rechtlich durch Arzneimittelverschreibungsgesetz verankert

minimale Implementierungsbarrieren

Clinical decision support tools present a more complex implementation scenario. While respondents recognised the substantial potential for improving prescription quality, they identified major technical barriers around integration with existing Austrian healthcare IT infrastructure, particularly ELGA (*elektronische Gesundheitsakte*, electronic health records) and e-medication platforms. The resource requirements for system development and staff training emerged as significant concerns; however, respondents suggested that a phased

CDST hohes Potenzial

erhebliche technische Integrationshürden

[11] Multicomponent interventions were defined as those incorporating two or more distinct components.

rollout, beginning with specialist practices and hospitals, could provide a viable implementation pathway. Acceptance levels were generally positive, particularly among digitally savvy practitioners, but implementation success would depend heavily on addressing technical integration challenges.

Bildungsinterventionen: hohe Akzeptanz durch Praxistauglichkeit und Autonomie-wahrendes Design

Personal als Hauptbarriere

Educational and awareness interventions received the most universally positive response across all survey participants. Respondents consistently described these approaches as "practical" ("*praxistauglich*") and noted their alignment with existing communication channels between insurance providers and healthcare practitioners. However, implementation barriers are centred on limited capacity within the ÖGK for comprehensive educational programs. The high acceptance of educational approaches reflects their non-threatening nature and support for professional decision-making, rather than constraining physician autonomy. Respondents suggested focusing on targeted, theme-specific campaigns.

Multikomponenten-Interventionen: große Skepsis wegen Komplexität und Ressourcenintensität

Multicomponent interventions faced the most significant implementation scepticism, with respondents expressing concerns about system complexity and resource intensity. The combination of multiple intervention elements was perceived as potentially overwhelming for healthcare providers, who were already facing significant time and resource pressures. Austrian context considerations revealed mixed responses regarding feasibility, with some recognition of potential benefits balanced against concerns about practical implementation within current healthcare system constraints. Acceptance levels were notably lower compared to other intervention types, with suggestions for pilot programs in selected regions before attempting any broader rollout.

Implementation Barriers and Facilitators in Austrian Healthcare

Systemintegration erfordert ELGA-Kompatibilität und bundesweite Standardisierung bei Datenschutzkonformität

System integration and technical infrastructure: While respondents recognised the potential benefits of digitally enabled interventions, they identified substantial technical barriers around integration with existing healthcare IT systems, particularly ELGA and e-medication platforms. Data privacy compliance with Austrian and EU regulations emerged as a non-negotiable requirement that could complicate implementation. Survey participants emphasised that standardisation across different healthcare providers and federal states would be essential to address current system fragmentation; however, they acknowledged that achieving such standardisation represents a significant structural challenge that requires a coordinated effort across multiple stakeholders.

Personal- und Zeitknappheit als fundamentale Barriere

Resource availability: Respondents identified excessive personnel and time requirements as fundamental implementation barriers. Limited staffing within ÖGK, constrained financial resources, and acute time pressures on healthcare providers emerged as pervasive concerns affecting all intervention types, with particular intensity for complex interventions. Respondents emphasised that successful implementation would require substantial system-level support and infrastructure investment, rather than relying on individual practice adoption.

professionelle Akzeptanz erfordert autonomie-unterstützendes statt restriktives Interventionsdesign

Professional autonomy and acceptance: respondents emphasised the importance of interventions being practical and designed to support rather than constrain prescribing decisions. Survey participants particularly emphasised that constructive rather than punitive framing would be essential for professional acceptance, noting that peer comparison interventions could trigger defensive reactions amongst healthcare professionals if perceived as judgmen-

tal. Implementation success was found to be heavily dependent on ensuring that interventions enhance rather than undermine clinical autonomy, indicating that the physician's consent would be crucial for the effectiveness of any intervention.

Benutzerfreundlichkeit als Akzeptanzfaktor

Quality assurance and usability: Survey participants emphasised that interventions must strike a careful balance between comprehensiveness and usability to avoid overwhelming time-pressured practitioners. Information accuracy, clinical relevance, and guideline conformity emerged as critical factors for professional acceptance; however, respondents noted that even high-quality content could fail if delivery mechanisms disrupted clinical workflow. Evidence-based content aligned with established clinical standards would be essential; however, implementation success would also depend on thoughtful interface design and integration into existing practice patterns.

bestehende Rechts- und Kommunikationsstrukturen erleichtern Implementierung bestimmter Nudges

Existing Infrastructure and Legal Frameworks: The respondents identified several existing structures that facilitate the implementation of interventions. Mandatory prescribing justification already exists through the Medical Prescription Law framework, which experts noted creates minimal implementation barriers for justification-based interventions. Participants highlighted that comparative elements for peer comparison already function through ÖGK mechanisms, providing a foundation for peer comparison interventions. Furthermore, respondents emphasised that established communication channels between ÖGK and healthcare practitioners could be leveraged for intervention delivery, reducing implementation complexity.

4 Discussion

Nudging als verhaltenswissenschaftliche Strategie zur Verschreibungsoptimierung

Despite the availability of evidence-based guidelines, prescribing decisions remain complex and nuanced, and suboptimal prescribing can lead to severe consequences, e.g. antibiotic resistance and a waste of resources. In recent years, nudging interventions have emerged as a promising strategy to optimise prescribing behaviour. Nudges are subtle modifications to choice architecture that influence behaviour without restricting freedom of choice, drawing on insights from behavioural science into human motivation and decision-making. In Austria, nudges have so far played a minor role in health policy strategies. Whilst some initiatives exist, including opt-out organ donation and the electronic reimbursement code (eEKO) for cost-effective medication selection, nudges may be introduced more widely. However, key questions remain about which nudging strategies have proven effective internationally and how they might be adapted to the Austrian context. Against this background, this report aimed to: (1) systematically identify and categorise nudging strategies that have been implemented internationally for optimising prescribing behaviour; (2) evaluate their effectiveness and safety; and (3) analyse their suitability for implementation within the Austrian healthcare system.

SR mit 3 Forschungsfragen (FF):
FF1: Identifikation und Kategorisierung der Nudges,
FF2: Effektivität und Sicherheit,
FF3: Implementierbarkeit in Ö

4.1 Summary of findings

FF1 + FF2:
11 RCTs mit 22 Nudging-Interventionen

zu Antibiotika (n=5), Opioiden (n=3) und sonstigen Medikamenten (n=3)

Risiko für Verzerrungen: niedrig bis hoch

To *research question one* (identifying nudges and categorisation systems) and *research question two* (effectiveness and safety), eleven RCTs [21-31] were included, which investigated a total of 22 nudging interventions for improving prescribing behaviour across antibiotic prescribing (n=5, [41-44, 51]), opioid prescribing (n=3, [45, 46, 50]), and other medications (n=3, [47-49]). Study scales ranged from 44 medical practices to over 5,000 physicians, with patient populations from 3,900 to over 330,000 participants. Study durations ranged from twelve to 24 months. The risk of bias (RoB) for outcomes in the included studies varied from low to high across different medication categories. For antibiotic prescribing studies, the RoB ranged from low to high, with concerns raised primarily regarding 'bias due to deviations from intended interventions', 'bias in measurement of the outcome', and 'bias in selection of the reported result'. Opioid prescribing studies demonstrated low to high risk of bias, predominantly due to 'bias due to deviations from intended interventions' and 'bias due to missing outcome data'. Studies examining other medication prescribing showed low risk of bias.

Peer-Vergleich:

klinische Entscheidungsunterstützungssysteme (CDST)

Bildungsinterventionen

Peer comparison emerged as the most prevalent approach, implemented through monthly email-based ranking systems, individualised feedback reports, and percentile-based performance benchmarking. Clinical decision support tools (CDSTs), which were also frequently tested, range from simple electronic health record (EHR) alerts to sophisticated predictive algorithms. Further approaches described were accountable justification mechanisms, which require written rationales that are permanently archived in patient records and educational outreach, involving structured visits from health insurance (HIRs) representatives who deliver evidence-based information and provide benchmarked feedback.

Using the ladder framework, nine interventions were classified as low-level (e.g. feedback visits, standardised letters, audit feedback), seven as mid-level (e.g. EHR pop-ups, alerts with justification requirements), and five as high-level (e.g. CDSTs). The Theoretical Domains Framework showed emotion, social influences, and behavioural regulation as the most common behavioural change factors (17, 17, and 16 interventions, respectively). MINDSPACE categorisation revealed ego and affect as predominant change drivers (19 interventions each), followed by messenger effects (15 interventions).

Kategorisierung nach Intensität, Verhaltensänderungsfaktoren und Verhaltenstreibern

Antibiotic prescribing: Five studies examined eleven nudging interventions across primary care settings in the UK, USA, France, and Canada. Low-level interventions showed mixed results. Peer comparison feedback reduced prescribing by 16.3%, and case-mix-adjusted feedback, combined with harm messaging, demonstrated a relative prescribing rate of 0.95 compared with control groups. Educational feedback visits alone did not show a significant impact. Mid-level interventions demonstrated partial statistical significance: accountable justification reduced total antibiotic prescribing rates compared with the control by 7%. Suggested alternatives showed no statistically significant effect compared to the control. However, both interventions reduced the rates compared to pre-intervention levels. Accountable justification requirements achieved an 18.1% absolute reduction in prescribing rates, while suggested alternative interventions resulted in a 16.0% absolute reduction. High-level interventions showed mixed patterns. A multicomponent intervention achieved an adjusted rate ratio of 0.88 for respiratory tract infection prescriptions (resulting in one fewer prescription per 62 patients annually), and CDSTs with educational visits reduced systemic antibiotic usage by 219.2 defined daily doses.

Antibiotika:
5 Studien mit 11 Nudges

UK, USA, Frankreich und Canada

Nudges mit stat. sig. Effekten vs. KG:
Peer-Vergleich, Verschreibungsbegründung, Mehrkomponenteninterventionen, CDST

Opioid prescribing: Three studies examined seven nudging interventions in primary care and surgical settings in the USA. Low-level interventions demonstrated consistent effectiveness. Individualised peer comparison reports resulted in 1.83 fewer opioid tablets prescribed per patient compared to controls, with 97.7% of participating surgeons reducing their prescribing patterns. Peer comparison feedback mechanisms significantly reduced prolonged opioid prescribing exceeding three months duration and concurrent opioid-benzodiazepine prescriptions. Combined interventions with individual audit feedback achieved reductions of 1.1-1.2 pills per prescription. Mid-level interventions showed mixed results. One study reported reductions of 3.6% with alerts alone and 1.9% with alerts plus peer comparison but lacked between-group comparisons. Another study found no significant effect of guideline checklist alerts on new prescriptions.

Opioide:
3 Studien mit 7 Nudges

USA

Nudges mit stat. sig. Effekten vs. KG:
Peer-Vergleich, individuelles Audit-Feedback

Other medication prescribing: Three studies examined four nudging interventions in primary care settings in the UK and USA. Low-level interventions showed mixed effectiveness for specific prescribing. One behavioural change outreach intervention demonstrated no significant differences for insulin initiation or blood pressure medication at 12-month follow-up. However, educational newsletters with feedback and theory-informed behavioural change components both significantly reduced high-risk prescribing of antipsychotics, non-steroidal anti-inflammatories, and antiplatelets compared to controls, with sustained reductions over time. One high-level intervention using an electronic clinical decision support tool (CDST) with comprehensive drug review significantly reduced the total number of prescribed drugs at 24-month follow-up.

sonstige Medikamente:
3 Studien mit 4 Nudges;
UK und USA

stat. sig. Effekte vs. KG:
Bildungsnewsletter + Feedback mit/ohne theoriegestützten Komponenten der Verhaltensänderung, CDST

Safety outcomes: Four studies examined safety outcomes of nudging interventions. For antibiotic prescribing, high-level interventions demonstrated reassuring safety profiles. One CDST intervention showed non-inferiority compared to controls in hospitalisation rates vs control and found no evidence of increased safety concerns across twelve outcomes, including pneumonia and peritonsillar abscess. Another multicomponent intervention showed no difference from usual care for safety outcomes. Mid-level interventions showed mixed safety results. Accountable justification combined with peer comparison resulted in significantly higher return visit rates for possible bacterial infections within 30 days following acute respiratory tract infection visits where antibiotics were not initially prescribed. Other mid-level interventions (suggested alternatives and accountable justification alone) showed no difference from usual care. For other medication prescribing, one high-level CDST intervention examining comprehensive drug review demonstrated a non-significant reduction in the composite outcome of unplanned hospital admission or death at 24 months. No safety outcomes were reported for opioid prescribing interventions.

nur 4 Studien mit Ergebnissen zur Sicherheit

überwiegend sichere Interventionen

1 kombinierte Intervention (Verschreibungsbegründung + Peer-Vergleich) erhöht stat. sig. die Wiederbesuchsrate

Economic outcomes: Overall, three studies examined economic outcomes of nudging interventions. For antibiotic prescribing, high-level interventions showed no evidence of cost differences between intervention and control groups. One study found no between-arm difference in dispensed amoxicillin and macrolide costs, whilst another reported mean NHS costs of -£1,999 with no significant difference, and no evidence that total healthcare utilisation costs differed during the trial period. For other medication prescribing, one low-level behavioural change outreach intervention demonstrated no significant differences in prescription costs between groups for glycaemic control medications or blood pressure medications. However, service use costs were significantly higher in the intervention group per patient compared to controls[12], representing an absolute difference of £2.85 per patient. No economic outcomes were reported for opioid prescribing interventions.

3 Studien mit ökonomischen Ergebnissen

Nudging-Interventionen überwiegend kostenneutral

To answer the *third research question* on implementation facilitators and barriers in the Austrian health care system, an expert consultation with three representatives from the Austrian social insurance sector revealed considerable variation in implementation feasibility across intervention types. Educational approaches received universally positive assessment, described as practical ("*praxistauglich*") and well-aligned with existing communication channels between insurance providers and healthcare practitioners. Mandatory prescribing justification mechanisms demonstrated high feasibility due to existing implementation through the legal framework.

Implementierbarkeit in Ö: universell positive Bewertung für praxistaugliche Ansätze mit bestehender Infrastruktur

CDSTs presented moderate implementation feasibility, with experts recognising substantial potential for prescription quality improvement whilst acknowledging substantial technical barriers related to integration with Austria's electronic health records (ELGA) and e-medication platforms. Peer comparison interventions received mixed assessments, with some comparative elements already existing through established insurance mechanisms.

CDST mit hohem Potenzial aber ELGA-Integrationshürden,

Peer-Vergleich teilweise etabliert

[12] This study aimed to improve type 2 diabetes management in primary care across multiple outcomes, including glucose-lowering and antihypertensive medication prescribing, foot examinations, and patient education; therefore, the costs encompass more than prescribing alone.

Mehrkomponenten-interventionen zu komplex und ressourcenintensiv

Multicomponent interventions received the most cautious assessment, with experts expressing major concerns about system complexity, resource intensity, and potential to overwhelm healthcare providers already facing substantial time pressures.

4.2 Critical interpretation

niedrigintensive Nudges konsistent wirksam, hochintensive Interventionen zeigen gemischte Ergebnisse

The systematic review findings reveal several interconnected patterns that illuminate both the promise and challenges of implementing nudging interventions in healthcare systems. Whilst multi-component interventions theoretically demonstrate the most significant potential impact by targeting diverse behaviours [5], our findings reveal a counterintuitive relationship between intervention complexity and effectiveness. Lower-intensity interventions consistently demonstrated effectiveness across all three medication categories, whereas high-intensity interventions yielded mixed results. This pattern suggests that the mechanisms driving prescribing behaviour change may be more responsive to consistent, contextually embedded nudges than to sophisticated technological solutions. This apparent paradox may reflect the burden imposed by complex systems, which can provoke resistance or workarounds amongst clinicians. Alternatively, lower-intensity interventions may align more effectively with the cognitive architecture of routine prescribing, where minor environmental modifications at the point of choice prove more influential than comprehensive, cognitively demanding technical solutions.

niedrigintensive Nudges möglicherweise besser kombinierbar mit routinemäßiger Verschreibungspraxis

soziale Anerkennung und berufliche Identität = starke Triebkräfte für klinisches Verhalten

The efficacy of simpler interventions is particularly evident in peer comparison mechanisms. The consistent effectiveness of this nudge across antibiotic and opioid prescribing indicates that social proof and professional identity remain powerful drivers of clinical behaviour. However, the prominence of ego and affect as the dominant behavioural drivers [17] may suggest these interventions succeed primarily through emotional engagement rather than rational deliberation.

Nudging wirft ethische Fragen zu Autonomie, Transparenz und paternalistischer Verhaltenskontrolle auf

This raises important ethical considerations regarding nudging strategies in clinical contexts. Interventions employing social comparison may achieve behavioural change by activating concerns about professional reputation rather than by enhancing clinical reasoning or evidence comprehension. Nudging has attracted ethical scrutiny concerning autonomy, consent, and paternalism, as it subtly influences decisions without explicit awareness, potentially undermining informed autonomous choice [11, 53]. This lack of transparency can lead to decisions individuals might not have made if fully informed, whilst the paternalistic assumption that implementing organisations know what constitutes optimal behaviour may limit professional judgement. The potential for misuse highlights the need for rigorous ethical frameworks to ensure that interventions are implemented transparently, respect professional judgement, and demonstrably enhance both clinician decision-making and patient outcomes rather than serving primarily administrative or financial objectives [53].

mögliche medikamentenspezifische Nudging-Effektivität

Furthermore, the effectiveness of nudging may be influenced by the medication category being addressed. The same intervention approach may succeed in optimising the prescription of a specific drug whilst showing a limited effect in another [8, 37, 54]. The medication-specific effectiveness pattern ne-

cessitates careful consideration during the planning process for implementation. The universal transferability of nudging strategies across prescribing contexts cannot be assumed; instead, intervention selection must be guided by the specific clinical domain and the prescribing behaviours targeted for optimisation.

langfristige Verhaltensänderung durch Nudging unsicher

Whilst nudges demonstrate effectiveness in influencing short-term behaviour, their capacity to sustain long-term change remains constrained [53]. This is also evident for nudges in the public health policy sector [13, 55, 56]. Over time, individuals may habituate to interventions or revert to established patterns once the immediate environmental prompt is removed, particularly when underlying motivations for behaviour change remain unaddressed or structural barriers to goal achievement persist [53]. Given that the included studies spanned twelve to 24 months, exceeding the 18 to 265 days typically required for behavioural habituation [57, 58], the effective nudges may have facilitated sustained behaviour change within the observation period. Nevertheless, the durability of these effects beyond the study endpoints remains uncertain, and extended follow-up would be necessary to determine whether behavioural changes persist, also once active intervention ceases.

Evidenzlücke bei Sicherheitsoutcomes

Verschreibungsreduktion führt zu Kompromissen zwischen Optimierung und dem Risiko einer Unterbehandlung

The limited safety data across studies represent a significant evidence gap, particularly given that these interventions are designed to modify clinical decision-making processes that directly affect patient outcomes. Thus, the increased return visit rates observed in one study raise important questions about unintended consequences. While reducing potentially inappropriate prescribing represents a positive outcome, the possibility of under-treatment leading to subsequent healthcare utilisation suggests that nudging interventions may create safety trade-offs that require careful monitoring and adjustment.

limitierte ökonomische Evidenz

keine bis höchstens minimale Unterschiede in Verschreibungskosten

Nudging-Interventionen oft teurer als vorab geschätzt

Prämisse des öffentlichen Wohls = bei budgetorientierten Umsetzungen im Kontext von Sparmaßnahmen problematisch

Also, the sparse economic evaluation data reveal a critical gap in understanding whether nudging interventions represent rational resource allocation within healthcare systems. The finding of "no to maximal minimal and non-significant differences in prescription costs" between intervention and control groups suggests that these behavioural interventions may not generate the anticipated cost savings that often motivate their implementation. However, a cost-effectiveness analysis [59] showed reduced costs when comparing three nudges (provider education on guidelines for respiratory tract infections, suggested alternatives, and accountable justification) to no intervention for antibiotic prescribing. Nevertheless, this remains an example within a broader literature characterised by insufficient economic evaluation, as noted by another systematic review [8]. Moreover, some analysts suggest that the costs of nudge research and implementation may exceed commonly reported estimates [60]. A core premise underlying nudging is the assumption that those who implement nudges, such as governments or healthcare organisations, act in the name of the public good and thus implicitly claim superior knowledge of what benefits individuals. In the context of current economic austerity, this premise raises concerns, as nudging interventions may be viewed as undermining professional autonomy in favour of objectives that are not universally accepted as serving the public good. Just as the private sector employs nudges for budget-driven reasons in marketing and sales, governmental and institutional use of nudges may be perceived against the backdrop of budgetary implications and cost-effectiveness rather than as genuinely serving patient welfare or clinical excellence [61].

Warnmeldungen und alternative Hinweise erhöhen möglicherweise kognitive Belastung, anstatt Arbeitsablauf zu vereinfachen

Implementing nudges inevitably imposes time and resource costs. EHR alerts represent one of the most prevalent delivery mechanisms for clinician-directed nudges. Evidence [62, 63] indicates that clinicians encounter more than 70 EHR alerts daily, dedicating over one hour to alert management, with each alert requiring approximately 8 seconds to review, translating to roughly 0.52 USD per alert. Beyond direct time costs, EHR alerts impose cognitive burdens by requiring task-switching, whereby clinicians must shift their attention between competing demands [64]. For example, 24 emergency department clinicians described EHR alerts as creating workflow fragmentation by impeding task offloading, imposing nonintuitive mental models, overloading clinicians with information, and reducing clinicians' sense of agency [65]. These cognitive costs have demonstrable consequences for decision-making quality, which deteriorates during periods of extensive decision-making (decision fatigue [66]), a phenomenon documented across diverse clinical settings. As not all clinician-directed nudges operate through EHR alerts, many alternative delivery mechanisms (such as emails comparing individual prescribing patterns with peer performance) face analogous challenges. These interventions target specific clinical behaviours whilst simultaneously imposing additional cognitive and administrative responsibilities on clinicians, thereby generating new sources of decision complexity rather than simplifying the clinical workflow[60].

Herausforderungen der Implementierung werden durch kontextuelle Einschränkungen verstärkt

z. B. länderspezifische Verschreibungstraditionen limitieren Generalisierbarkeit auf Österreich

These implementation challenges are compounded by contextual limitations that constrain generalisability. Nine of the eleven studies included in the systematic review were conducted in primary care settings, which limits the transferability of the findings to other healthcare sectors. Moreover, the included studies were predominantly undertaken in countries whose healthcare systems differ substantially from Austria's, creating uncertainty regarding the applicability of results to the Austrian context. Country-specific prescribing traditions further complicate transferability; whilst antibiotic optimisation represents a priority concern in Austria, opioid prescribing patterns differ markedly from those in the United States, where most opioid intervention studies were conducted. These prescribing traditions reflect not merely variations in clinical practice but also embedded patient expectations regarding medication use, which influence both prescribing behaviour and intervention receptivity.

Implementierungserfolg abhängig von bestehender Infrastruktur und systemischen Rahmenbedingungen

As the implementation success of nudges depends critically on existing healthcare infrastructure and systemic framework conditions [5], there is an inherent tension between the effectiveness of interventions and resource requirements. The Austrian expert consultation demonstrates this tension concretely. Educational interventions and mandatory justification received high feasibility ratings due to Austria's well-established insurance-provider communication channels and existing legal frameworks [52] for prescribing accountability. Conversely, technical barriers and the need for high-quality, standardised data to support CDST underscore the limitations of digital health infrastructure in terms of maturity, which constrain implementation options. Challenges in ELGA and e-medication integration suggest that even effective interventions may face substantial delays in healthcare systems with less developed interoperability frameworks.

regionale Fragmentierung zwischen den österreichischen Bundesländern: weitere Herausforderung für Implementierung

The regional fragmentation across Austrian federal states illustrates broader scaling challenges that compound these implementation considerations. Federal healthcare systems require contextually appropriate comparisons and standardisation across regions, suggesting that successful national implementation demands substantial customisation rather than uniform deployment. This fragmentation multiplies the resource requirements for system-wide implementation whilst potentially diluting intervention effectiveness through inconsistent application.

zu beachtende Schlüsselfaktoren vor Implementierung: z. B. schrittweises Vorgehen, klare Definition der Zielgruppen und Maßnahmen, umfassende Systemintegrationsplanung, Ausbildung von Gesundheitspersonal, Monitoring, Ressourcenplanung

Before implementing nudging interventions, several key considerations are essential. A phased approach, beginning with high-feasibility interventions, such as educational outreach and mandatory prescribing justification, leveraging existing infrastructure, should precede complex mechanisms like CDSTs, which require a staged rollout. A clear definition of target populations and intervention scope is critical; interventions must specify which prescriber groups, clinical settings, and medication categories will be prioritised to ensure focused implementation. Comprehensive system integration planning must address technical compatibility with ELGA and e-medication platforms, while ensuring data privacy compliance with Austrian and EU regulations. This requires coordination across Austria's fragmented healthcare IT landscape and standardisation protocols spanning federal states. Healthcare personnel training programmes must emphasise that interventions support rather than constrain clinical autonomy, addressing workflow integration to prevent information overload and alert fatigue. Monitoring of pilot projects should include comprehensive resource and cost analyses that account for all expenses, including implementation costs, and extend beyond prescribing outcomes to assess potential unintended consequences. This should encompass patient safety indicators and adverse effects, such as increased hospitalisation rates or delayed necessary prescriptions. Resource planning must account for development costs, maintenance expenses, and sustained stakeholder engagement, incorporating physician perspectives throughout implementation. Implementation success depends on alignment with existing infrastructure, realistic resource allocation, and maintained professional acceptance over time.

4.3 Limitations

Selektionslimitationen durch strikte Inklusionskriterien

Several limitations must be acknowledged in this systematic review. First, despite conducting a comprehensive systematic search for nudging interventions, relevant primary studies may have been overlooked. The challenge lies in the broad conceptual scope of nudging, as various behavioural interventions can function as nudges without being explicitly labelled as such in the literature. Additionally, our application of specific inclusion and exclusion criteria may have limited the selection of trials (e.g., only nudges that targeted practitioners) that could have contributed valuable efficacy data, particularly regarding safety outcomes.

Kategorisierung der Nudges durch Autorinnen

A second limitation related to the manual search procedures used to categorise nudges and the subsequent author-led classification (by VH and JAP) of nudging interventions. The categorisation remains subject to expert interpretation and potential disagreement. Whilst we applied established frameworks systematically and to the best of our professional judgement, alternative clas-

sifications by nudging specialists might yield different results. This limitation reflects the inherent subjectivity in categorising complex behavioural interventions across multiple theoretical frameworks.

methodische Qualität der inkludierten Studien

Third, the methodological quality of included studies presents another limitation for this assessment. Most outcomes of the included trials were rated as "some concerns" for risk of bias, primarily due to inherent awareness bias in cluster-randomised designs, where participants were aware of their trial participation and intervention assignment, which may have independently influenced prescribing behaviour beyond the intended nudge effect. Safety outcome assessment was hindered by reliance on self-reported practice-level data rather than objective patient-level outcomes, thereby limiting confidence in conclusions regarding antibiotic interventions. Evidence quality varied considerably across medication categories, with trials examining polypharmacy and cardiovascular medications demonstrating low risk of bias. In contrast, antibiotic trials consistently showed methodological concerns and opioid trials ranged from low to high risk due to substantial attrition. Additionally, selective reporting concerns were identified in multiple trials. These methodological limitations necessitate cautious interpretation of findings.

kleine Expert:innengruppe (n=3) und fehlende Ärzt:innen-Perspektiven limitieren Implementierungsperspektiven

Fourthly, resource constraints necessitated limiting the feasibility assessment of implementation to social insurance sector experts. The small sample size of four social insurance experts, of whom only three completed the questionnaire, represents a significant limitation, as it does not yield representative results but rather provides initial exploratory insights. A larger sample might have revealed additional important information and perspectives that remained uncaptured in this assessment. Furthermore, healthcare practitioners who would be directly affected by these nudging interventions may hold substantially different perspectives regarding implementability, barriers, and acceptability compared to policy and administrative stakeholders. This limitation is particularly significant given the emphasis on professional autonomy that emerged from our findings, suggesting that clinician perspectives are essential for comprehensive implementation planning.

5 Conclusion

Nudging-Interventionen zur Optimierung des Verschreiberverhaltens von Ärzt:innen

This systematic review addressed nudging interventions for optimising prescribing behaviour in healthcare settings, examining effectiveness across antibiotic, opioid, and other medication categories. The report synthesised evidence from eleven RCTs, categorised the identified nudging mechanisms using established behavioural frameworks, and evaluated the feasibility of implementation within the Austrian healthcare context through expert consultation.

Evidenz weist auf Effektivität von Nudges hin, allerdings limitieren Evidenzlücken bei Sicherheits- und ökonomischen Outcomes die Aussagekraft

The evidence suggests that nudging interventions can effectively modify prescribing behaviour, with lower-intensity interventions consistently outperforming high-intensity approaches while requiring fewer resources. Peer comparison mechanisms proved particularly effective across medication categories. However, the evidence base remains limited by insufficient safety evaluation, geographic concentration of studies, and sparse data on economic outcomes. Notably, the current evidence does not demonstrate cost savings from nudging interventions, leaving the actual economic impact uncertain.

österreichische Expert:innen: heterogene Implementierbarkeit der Nudges

An Austrian expert consultation revealed significant variations in the feasibility of implementation among nudges. Educational approaches and mandatory justification demonstrated high feasibility due to the alignment of existing infrastructure. In contrast, CDSTs faced technical integration barriers, and multicomponent interventions faced concerns about resource intensity. Critical implementation barriers include resource constraints, technical integration challenges with ELGA and e-medication systems, and professional autonomy considerations favouring supportive over restrictive interventions.

erfolgreiche Implementierung erfordert Phasenansatz, Systemintegration und kontinuierliches Stakeholder-Engagement

For Austrian policymakers moving forward with implementing nudging interventions, several key considerations must be addressed (see Figure 5-1): a phased approach beginning with high-feasibility interventions, a clear definition of the target population, comprehensive system integration to ensure technical compatibility and data privacy compliance, healthcare personnel training programmes, and ongoing monitoring of intended outcomes, potential unintended consequences and resource use. Resource planning must account for development costs, maintenance expenses, and stakeholder engagement strategies, incorporating physician perspectives to ensure the acceptability and sustainable implementation of interventions across the Austrian healthcare system.

Figure 5-1: Key considerations for implementing nudges

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Appendix

Table A-1: Search strategy for primary studies in Ovid MEDLINE

Database: Ovid MEDLINE(R) ALL <1946 to June 06, 2025> Search Strategy:	
Search date: 07.06.2025	
#1	nudg*.mp. (2955)
#2	behavio?r* economic* informed intervention*.mp. (9)
#3	(choice adj architect*).mp. (349)
#4	(theoretical adj domain adj framework*).mp. (106)
#5	(behavio?r* adj change adj (wheel* or technique* or intervention* or process* or method* or strateg*)).ti,ab. (6407)
#6	(behavio?r* adj5 prescribing).mp. (2168)
#7	*Inappropriate Prescribing/pc [Prevention & Control] (1095)
#8	feedback intervention*.mp. (935)
#9	(social norm adj5 feedback).mp. (20)
#10	(prescri* adj injunction*).mp. (3)
#11	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 (13630)
#12	prescri*.mp. (329009)
#13	*Clinical Decision-Making/ (5611)
#14	((clinical or medical) adj decision-mak*).ti,ab. (39507)
#15	12 or 13 or 14 (371156)
#16	11 and 15 (3780)
#17	(physician* or doctor* or GP* or MD medic$1 or surgeon* or nurse* or p?ediatr* or clinician* or therapist* or pathologist* or psycho?therapist* or psycho-therapist* or psychiatrist* or psychologist* or dentist* or dieti#ian* or HCP* or HCW* or internist* or nutritionist* or obstetrician* or psychiatrist* or radiologist* or optometrist* or pharmacist* or medical assistant* or midwi#e* or audiologist* or phlebotomist* or physio?therapist* or physio-therapist* or interventionist*).mp. (2895792)
#18	16 and 17 (2749)
#19	limit 18 to dt=20190601-20250607 (1108)
#20	remove duplicates from 19 (1098)

Table A-2: Key theoretical domains of the Theoretical Domain Framework and associated constructs

Domain	Definition	Constructs
Knowledge	Awareness of the existence of something.	Knowledge, procedural knowledge, knowledge of the task environment
Skills	Ability or proficiency acquired through practice.	Skills, skills development, competence, ability, interpersonal skills, practice, skill assessment
Social/Professional Role and Identity	A coherent set of behaviours and displayed personal qualities of an individual in a social/work setting.	Professional identity, professional role, social identity, professional boundaries, professional confidence, group identity, leadership, organisational commitment
Beliefs about Capabilities	Acceptance of the truth, reality, and validity about an ability, talent or faculty that a person can put to constructive use.	Self-confidence, perceived competence, self-efficacy, perceived behavioural control, beliefs, self-esteem, empowerment, professional confidence
Optimism	Confidence that things will happen for the best or that desired goals will be attained.	Optimism, pessimism, unrealistic optimism, identity
Beliefs about Consequences	Acceptance of the truth, reality, or validity of a behaviour in a given situation.	Beliefs, outcome expectancies, characteristics of outcome expectancies, anticipated regret, and consequents
Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus.	Incentives, punishment, consequences, reinforcement, contingencies, sanctions
Intentions	A conscious decision to inform a behaviour or to resolve to act in a certain way.	Stability of intentions, the transtheoretical model and stages of change
Goals	Mental representations of outcomes or end states that an individual wants to achieve.	Goal priority, goal/target setting, goals (autonomous/controlled), action planning, implementation intentions
Memory, Attention and Decision Processes	Ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives.	Memory, attention, attention control, decision-making, cognitive overload/tiredness
Environmental Context and Resources	Any circumstances of a person's situation or environment that discourage or encourage the development of skills and abilities, independence, social competence and adaptive behaviour.	Resources/material resources, organisational culture/climate, salient events, critical incidents, person X environment interaction, barriers and facilitators
Social Influences	Those interpersonal processes that can cause individuals to change their thoughts, feelings or behaviours.	Social norms, group conformity, social comparison, group norms, social support, power, intergroup conflict, alienation, group identity, modelling
Emotion	A complex reaction pattern involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event.	Fear, anxiety, affect, stress, depression, positive/negative affect, burnout
Behavioural Regulation	Anything aimed at managing or changing objectively observed actions.	Self-monitoring, breaking habits, and action planning

Table A-3: Components of the MINDSPACE framework

Components	How they target us:	How the components work:
Messenger	We are heavily influenced by who is communicating information.	■ There is evidence that people are more likely to act on information if experts deliver it. ■ Demographic and behavioural similarities between the expert and the recipient can improve the effectiveness of the intervention. ■ Example: Health interventions delivered by research assistants and health educators were more effective at changing behaviour than those delivered by trained facilitators or teachers, and health educators were usually more persuasive than research assistants.
Incentives	Our responses to incentives are shaped by predictable mental shortcuts, such as the strong desire to avoid losses.	■ The impact of incentives clearly depends on factors such as the type, magnitude and timing of the incentive. ■ Incentives often do not involve money but, more generally, change the costs and benefits of behaving in particular ways. ■ Example: One study on weight loss asked some participants to deposit money into an account, which was returned to them (with a supplement) if they met weight loss targets. After seven months, this group had shown significant weight loss compared to their initial weight. The weight of participants in the control group remained unchanged.
Norms	We are heavily influenced by what others do.	■ Norms can be explicitly stated („No Smoking" signs in public places) or implicit in observed behaviour (shaking the hand of someone you meet for the first time) ■ Example: In a hotel towel recycling study, different sign messages yielded varying compliance rates: 35.1% recycled when asked to help the environment, 44.1% when social norms were added and most hotel guests were told to recycle, and 49.3% when told that most previous occupants of that specific room had recycled their towels.
Defaults	We "go with the flow" of pre-set options.	■ Defaults are the options that are pre-selected if an individual does not make an active choice ■ Defaults exert influence as individuals regularly accept whatever the default setting is, even if it has significant consequences. ■ Example: Ventilators help critically ill patients breathe in intensive care units by delivering controlled air volumes to the lungs. While doctors typically set these volumes, excessively high volumes can damage the lungs. A research study changed the ventilators' default settings to deliver lower volumes of air into patients' lungs. The mortality rate was 25% lower with the new setting.
Salience	Our attention is drawn to novel things that seem relevant to us.	■ People are more likely to register stimuli that are novel (messages in flashing lights), accessible (items on sale next to checkouts) and simple (a snappy slogan). ■ Simplicity is essential here because our attention is much more likely to be drawn to things that we can understand – to those things that we can easily „encode". ■ We are much more likely to encode things presented in ways that relate directly to our personal experiences than those presented in a more general, abstract manner. ■ Example: The size of the current national health service (NHS) budget is more salient when expressed as an amount per taxpayer than as the overall amount.
Priming	Our actions are often influenced by subconscious cues.	■ People behave differently if they have been „primed" by specific cues beforehand ■ Many things can act as primes, including words, sights, smells ■ Example: Placing particular objects in one's environment can alter behaviour – „situational cues" like walking shoes and runners' magazines may prime a "healthy lifestyle" in people
Affect	Our actions can be powerfully shaped by our emotional associations.	■ Emotional responses to words, images and events can be rapid and automatic, so that people can experience a behavioural reaction before they realise what they are reacting to. ■ Example: A study of direct mail loan advertisements found that the content of the advertisements significantly affected uptake beyond pricing alone. Specifically, including a picture of an attractive, smiling woman increased loan demand as much as reducing the interest rate by 25%.
Commitments	We seek to be consistent with our public promises and to reciprocate actions.	■ We tend to procrastinate and delay making decisions that are likely to be in our long-term interests. ■ The very act of writing a commitment can increase the likelihood of it being fulfilled, and commitment contacts have already been used in some public policy areas. ■ Example: Students are willing to self-impose costly deadlines to help them overcome procrastination
Ego	We act in ways that make us feel better about ourselves.	■ We tend to behave in a way that supports the impression of a positive and consistent self-image. ■ When things go well in our lives, we attribute it to ourselves; when they go badly, it's the fault of other people, or the situation we were put in –an effect known as the „fundamental attribution error" ■ Example: Sports fans demonstrate this effect through biased memories of their team's performance. While impartial observers see both teams committing equal fouls in a match, partisan fans systematically misremember and misinterpret the game, recalling far more fouls by the opposing team than their own.

Abbreviation: NHS … National Health Service

Table A-4: Key principles and description of the EAST framework

Key principle	Short description	Approaches:
Easy	Designing policies that require minimal effort.	1. Make the desired behaviour the default option. 2. Reduce friction for preferred choices while increasing it for unwanted ones. 3. Keep messages simple and clear, as complex information tends to be ignored.
Attractive	To ensure policy adoption, visibility is key.	1. Capture attention through striking visuals, colours, and personalisation. 2. Offer appealing incentives to encourage participation. 3. Make engagement worthwhile through financial rewards, lotteries, or "gamification" that transforms policy activities into enjoyable experiences.
Social	Humans are inherently social creatures who once depended on group membership for survival	1. Introducing policies during major life transitions when people are naturally more receptive to changing habits 2. Managing the timing of costs and benefits strategically, recognising that people focus heavily on their present well-being 3. Addressing the challenge of policies with high immediate costs but delayed benefits (like healthcare system expansions that raise taxes now but deliver improvements years later) 4. Increasing immediate benefits or reducing upfront costs whenever possible to improve program adoption
Timely	Timing is crucial for policy implementation.	1. Introducing policies during major life transitions when people are naturally more receptive to changing habits. 2. Managing the timing of costs and benefits strategically, recognising that people focus heavily on their present well-being. 3. Addressing the challenge of policies with high immediate costs but delayed benefits (like healthcare system expansions that raise taxes now but deliver improvements years later). 4. Increasing immediate benefits or reducing upfront costs whenever possible to improve program adoption.

Table A-5: Key principles and a short description of the FORGOOD framework

Key principle	Short description
Fairness	Does the behavioural policy have undesired redistributive effects?
Openness	Is the behavioural policy open or hidden and manipulative?
Respect	Does the policy respect people's autonomy, dignity, freedom of choice and privacy?
Goals	Does the behavioural policy serve good and legitimate goals?
Opinions	Do people accept the means and the ends of the behavioural policy?
Options	Do better policies exist and are they warranted?
Delegation	Do the policy-makers have the right and the ability to nudge using the power delegated to them?

Table A-6: Data extraction table of fandomised controlled trials investigating nudges for antibiotic prescriptions

Author, year	Blair, 2023 [41]	Gulliford, 2019 [42]	Meeker, 2016 [43]	Jeanmougin, 2024 [44]	Schwartz, 2024 [51]
Country	UK	UK	USA	France	Canada
Drug	Antibiotics	Antibiotics	Antibiotics	Antibiotics	Antibiotics
Study design	Cluster randomised controlled trial	Cluster randomised controlled trial	Cluster randomised controlled trial	Cluster randomised controlled trial	RCT
Study duration (months)	12	12	18	18	18
Setting	General practitioner (GP) practices, primary care	General practices, primary care	Primary care practices	GP, primary care	Primary care, general practice or family medicine
Recruited practices, n	294 IG: 144 CG: 150	80 IG: 42 CG: 38	47 IG1: 6 IG2: 7 IG3: 4 CG: 6	2501 practice: IG1: 403 IG2: 402 CG: 402	5097 physicians IG: 4076; IG1: 1026, IG2: 1020, IG3: 1012, IG4: 1018 CG: 1021
Included patients (n)	336,496	NI	16,959 patient visits	NI	NI
Intervention group (IG)	CHICCO intervention	Multicomponent intervention	*Three behavioural interventions, implemented alone or in combination:* IG1: Suggested alternatives IG2: accountable justification IG3: peer comparison	IG1: Feedback visit IG2: Clinical decision support system (CDSS)–based intervention	Case-mix adjusted feedback, harms messaging, neither, or both: IG1: Adjusted data and harms information IG2: Adjusted data and no harms information IG3: Unadjusted data and harms information IG4: Unadjusted data and no harms information
Comparator group (CG)	No intervention	No intervention	No intervention	Routine visit by the regional health insurance representative (HIR), but the discussion focused on a health priority other than antibiotic prescription	No intervention
Primary endpoint(s)	The rate of amoxicillin and macrolide items dispensed. The rate of hospitalisations for respiratory tract infections (RTI).	The rate of antibiotic prescriptions for self-limiting RTIs over the 12-month intervention period.	The primary study outcome was the antibiotic prescribing rate for antibiotic-inappropriate acute respiratory tract infection visits and no concomitant reason for antibiotic prescribing.	Total volume of systemic antibiotics dispensed as defined daily doses (DDD; according to the World Health Organisation) per participating GP at the end of 12 months of follow-up.	Antibiotic prescribing rate per 1,000 patient visits for patients 65 years or older, six months after intervention.
Target group of drugs	Children 0 – 9 years	No age restrictions	Adults	Adults	Adults aged 65 or older

Author, year	Blair, 2023 [41]	Gulliford, 2019 [42]	Meeker, 2016 [43]	Jeanmougin, 2024 [44]	Schwartz, 2024 [51]
Efficacy					
Total (antibiotic) prescribing	No evidence of antibiotic reduction between groups	No evidence that total antibiotic prescribing was reduced by the intervention for antibiotic prescribing for all indications.	*Mean antibiotic prescribing rates baseline vs. 18 months follow-up (FU) (absolute difference, AD)*: CG: 24.1% vs. 13.1% (AD: -11.0%); IG1: 22.1% to 6.1% (AD: -16.0%; difference in differences, -5.0% [95% CI, -7.8% to 0.1%]; *p*=.66 for differences in trajectories); IG2: 23.2% to 5.2% (AD: -18.1%; difference in differences, -7.0% [95% CI, -9.1% to -2.9%]; *p*<.001); IG3: 19.9% to 3.7% (AD: -16.3%; difference in differences, -5.2% [95% CI, -6.9% to -1.6%]; *p*<.001) There were no statistically significant interactions between interventions.	Decrease in the mean volume of antibiotics dispensed per GP, *12-month FU:* IG1 vs. CG: -109.7 (SD 62.4; 95% CI -232.0 to 12.5 *p*=.08) IG2 vs. CG: -219.2 (SD 61.4; 95% CI -339.5 to -98.8; *p*<.001)	Mean antibiotic prescribing rate per 1000 patient visits, *6-month FU, mean (standard deviation, SD):* IG[1] vs. CG 56.0 (39.2) vs 59.4 (42.0); relative rate 0.95 (95% CI 0.94 to 0.96) Mean antibiotic prescriptions dispensed between baseline vs. 12 months FU: (0.96 (0.95 to 0.97))
Prescriptions of specific antibiotics/ for specific cases	NI	*Antibiotic prescriptions for RTI per 1,000 patient-years:* IG vs. CG: 98.7 vs. 107.6, unadjusted RR of 0.92, [adjusted antibiotic-prescribing rate ratio (RR) 0.88 (95% CI 0.78 to 0.99; *p*=.040)] *Antibiotic prescribing for RTI in adults aged between 15 and 84 years, absolute risk reduction:* -16.0 (95% CI 5.0 to -25.1). One antibiotic prescription was avoided for every 62 (95% CI, 40-200) registered patients aged 15-84 years per year. No evidence of effect in children aged <15 years or adults aged ≥85 years.	There was no evidence on the reduction of inappropriate antibiotic prescription for any intervention group.	*Reduction of prescriptions, 12 months FU, mean difference (MD, 95% CI) vs. control group:* Critical antibiotics: IG1: -101.3 (-148.1 to -54.5, *p*<.001) IG2: - 96.2 (-143.2 to -49.2, *p*<.001) Cephalosporins: IG1: -24.2 (37.8 to – 10.7; *p*=.001) IG2: -19.8 (-33.4 to -6.2; *p*=.005) Quinolones: IG1: -15.9 (-28 to -3.7, *p*=.011) Amoxicillin-clavulanic acid: IG1: -63.3 (-98.6 to – 28; *p*<.001) IG2: -64 (-99.4 to – 28.5; *p*<.001) In the IG2, there was also a reduction in the volume of prescriptions for patients aged >65 years [-42.1 (-83 to -1.2; P=0.044)] and <6 years [-20 (-31.4 to -8.5; *p*=.001)]	***Per 1,000 patient visits, 6 months FU, relative rate*** *Antibiotic prescribing rate for broad-spectrum prescriptions* IG vs. CG: 26.0 vs. 28.4, 0.94 (0.92 to 0.95) *Antibiotic prescribing that was likely unnecessary* IG vs. CG: 7.5 vs. 8.6, 0.89 (0.86 to 0.92) *Antibiotic prescribing rate for long-duration prescriptions* IG vs. CG: 13.7 vs 16.5, 0.85 (0.83 to 0.87)

Author, year	Blair, 2023 [41]	Gulliford, 2019 [42]	Meeker, 2016 [43]	Jeanmougin, 2024 [44]	Schwartz, 2024 [51]
Safety					
Rate of return visits/hospitalisation	***Rate of hospitalisation for RTI:*** IG [0.019 (95% CI 0.014 to 0.026)] vs. CG [0.021 (95% CI 0.014 to 0.029)], was non-inferior [relative risk = 0.952 (95% CI 0.905 to 1.003)]	NI	Rate of return visits for possible bacterial infections within 30 days following visits for acute RTI (both antibiotic-inappropriate and potentially antibiotic-appropriate) in which antibiotics were not prescribed: CG: 0.43% (95% CI, 0.25% to 0.70%) Accountable justification plus peer comparison group (IG2+IG3): statistically significant higher rate of such return visits (1.41% [95% CI, 1.06% to 1.85%])	NI	NI
Harms	***Serious adverse events (SAEs): 4*** Fatality: 3 (1 CG; 2 IG unrelated to the intervention). Hospitalisation: 1 (IG)	No evidence that 12 safety outcomes, including pneumonia and peritonsillar abscess, might be increased as a result of the intervention.	NI	NI	NI
Economic outcomes					
Prescription costs	There was no evidence of a between-arm difference when comparing the costs of dispensed amoxicillin and macrolides	NI	NI	NI	NI
Service use costs	The economic evaluation found no evidence of a difference in mean National Health Service costs between arms; mean difference -£1,999 (95% confidence interval -£6,627 to 2,630)	No evidence that the total costs of health-care utilisation might differ as a result of intervention, at least during the time horizon of the trial.	NI	NI	NI
Implementation outcomes					
Costs of intervention	The costs of the intervention were estimated as £210 per practice (which comprised the non-research related costs involved at the practice level that arose from integrating the intervention into local computers, and training costs borne at the practice level).	NI	NI	NI	NI

Author, year	Blair, 2023 [41]	Gulliford, 2019 [42]	Meeker, 2016 [43]	Jeanmougin, 2024 [44]	Schwartz, 2024 [51]
Use of the intervention	***Median usage across the practices, 12 months FU:*** n=115: 70 uses (IQR 9-142)	***Utilisation of DSTs of RTI consultations:*** Lowest quartile: < 1%, Highest quartile: up to 28% In adults aged 15-84 years, there was evidence of a linear trend across DST utilisation quartiles (adjusted RR 0.96, 95% CI 0.93 to 0.99). This association was not evident among children, the senior elderly, or, only weakly, the sample as a whole (adjusted RR 0.97, 95% CI 0.93 to 1.00; *p*=**.043**).	NI	NI	NI
Feedback from practitioners	***Qualitative evaluation:*** Clinicians liked the intervention and used it as a supportive aid, especially with borderline cases. However, it did not always integrate well within the consultation flow and was used less over time.	***Process evaluation questionnaire:*** 51 respondents from 31 of 41 (76%) intervention-trial-arm practices. Respondents gave positive feedback on monthly antibiotic prescribing reports, finding them credible, easy to understand, useful for discussion with colleagues, and beneficial for practice. However, fewer respondents (<80%) agreed the reports encouraged reduced prescribing or impacted practice prescribing. The webinar was well-received. Decision support tools were less favourably received than prescribing reports, with nearly one-third not affirming that the tools would support reduced antibiotic prescribing.	NI	NI	NI

Abbreviations: AD … absolute difference; aOR … adjusted odds ratio; CG … control group; CI … confidence interval; DST … decision support tool; HIR … health insurance representative; FU … follow-up; IG … intervention group; MD … mean difference, n … number; NI … no information; p … p-value; RR … risk rate; RTI … respiratory tract infection; UK … United Kingdom; USA … United States of America; SAE … serious adverse event; vs. … versus

Table A-7: Data extraction table of randomised controlled trials investigating nudges for opioid prescriptions

Author, year	Dun, 2023 [50]	Kraemer, 2022 [45]	Navathe, 2022[67]
Country	USA	USA	USA
Drug	Opioids	Opioids	Opioids
Study design	Randomised controlled trial	Cluster randomised controlled trial	Cluster randomised controlled trial
Study duration (months)	12	12	18
Setting	Outlier surgeons, secondary care	Primary care clinics	Emergency department (ED) and urgent care (UC), secondary care
Randomised practices	489 surgeons IG: 245 CG: 244	48 IG1: 12 IG2: 12 IG3: 12 CG: 12	438 clinicians of 21 EDs and 27 UCs IG1: 119 IG2: 112 IG3: 102 CG: 105
Included patients (n)	Median number per surgeon: 14	22,616	294,962
Intervention group (IG)	Individualised report with cover letter, report and educational guidance	IG1: Alert with guideline checklist requiring free-text Justification for opioid prescribing decisions IG2: Monthly email feedback on initial opioid prescriptions for acute pain, guideline adherence, and peer comparison IG3: All interventions combined	IG1: Individual audit feedback IG2: Peer comparison feedback IG3: Combination of IG1 + IG2
Comparator group (CG)	No intervention	Alert containing a guideline with a short checklist of recommendations	No intervention
Primary endpoint(s)	Surgeon-level change in the average number of perioperative morphine milliequivalent (MME) that corresponded to a tablet of 5mg of oxycodone (opioid tablet) prescribed per patient before and after the intervention.	Receipt of an initial opioid prescription at the qualifying clinic visit	The change in pills per opioid prescription from the preintervention period to the intervention period.
Target group of drugs	NI	Adults	NI
Efficacy			
(Total) opioid prescribing	*Mean change in average number of tablets, post-intervention:* *IG vs. CG:* 10.54 (SD 5.34) vs. 12.30 (SD 6.02), *p*=.04) *Mean of the average number of tablet prescriptions*: IG vs. CG: -14.3% *Mean number of opioid tablets prescribed per patient, multivariable linear regression model*: *IG vs. CG:* -1.83 tablets (95% CI: -3.61to -0.04; *p*=.04)	*Opioid prescribing reduction:* 3.1% in the total sample 4.2% in CG 3.6% in IG1 2.6% in IG2 1.9% in IG3	*Decrease in pills per prescription during intervention vs. CG, adjusted analyses:* CG: NA IG1: -0.3, not statistically significant (n.s.s.) IG2: -0.8; 95% CI: -1.4 to -0.3; *p*=.003) IG3: -1.2; 95% CI: -1.8 to -0.7; *p*<.001). *"Main effects" of each single intervention alone relative to usual care:* CG: NA IG1: -0.4, n.s.s.

Author, year	Dun, 2023 [50]	Kraemer, 2022 [45]	Navathe, 2022[67]
(Total) opioid prescribing *(continuation)*	Pre vs. post intervention: IG: - 9.45 (p<.001), 97.7% (n = 85/87) of surgeons in the intervention group reduced their opioid prescribing pattern. CG: - 9.27 (p<.001)		IG2: -0.9; 95% CI: -1.3 to -0.5; p<.001 IG3: NA *Decrease in pills per prescription after follow-up vs. CG, adjusted analyses:* CG: NA IG1: 0.0, n.s.s. IG2: -1.0; 95% CI: -1.8 to -0.3; p<.007 IG3: -1.1; 95% CI: -1.9 to -0.3; p=.008 *"Main effects" of each single intervention alone relative to usual care:* CG: NA IG1: 0.1, n.s.s. IG2: -1.1; 95% CI: -1.6 to -0.5; p<.001 IG3: NA
Prescriptions of specific opioids/for specific cases	NI	Opioid prescribing at the index visit was lower in the pooled comparison (main effects) model (adjusted odds ratio [aOR], 0.60; 95% CI, 0.38 to 0.96) throughout the total intervention period and after the comparison emails were sent *aOR for prolonged opioid prescribing of more than 3 months:* *IG2 vs. CG:* 0.79 (95% CI, 0.69-0.91; p=.001) *aOR for concurrent opioid/benzodiazepine prescription*: *IG2 vs. CG:* 0.85 (95% CI, 0.72 to 1.00; p=.04) *aOR for a new opioid prescription:* *IG1 vs. CG*: 0.74 (95% CI, 0.46 to 1.18; p=.20) *IG2 vs. CG*: 0.60 (95% CI, 0.38 to 0.96; p=.03)	NI
Safety			
Rate of return visits/ hospitalisation	NI	NI	NI
Harms	NI	NI	NI
Prescription costs	NI	NI	NI
Service use costs	NI	NI	NI
Costs of intervention	NI	NI	NI
Use of the intervention	NI	NI	NI
Feedback from practitioners	NI	NI	NI

Abbreviations: AD … absolute difference; aOR … adjusted odds ratio; CG … control group; CI … confidence interval; DST … decision support tool; ED … emergency department; FU … follow-up; IG … intervention group; n … number; NA … not applicable; NI … no information; n.s.s. … not statistically significant; p … p-value; RTI … respiratory tract infection; UC … urgent care; USA … United States of America; vs. … versus;

Table A-8: Data extraction table of randomised controlled trials investigating nudges for other medication prescriptions

Author, year	Presseau, 2018 [47]	Rieckert, 2020 [48]	Guthrie, 2016 [49]
Country	UK	Europe	UK
Drug	Blood pressure and glycaemic control	Polypharmacy	Antipsychotics, non-steroidal anti-inflammatories, and antiplatelets
Study design	Cluster randomised controlled trial	Cluster randomised controlled trial	Cluster randomised controlled trial
Study duration (months)	12	24	12
Setting	General Practice, primary care	General Practice, primary care	Primary care practices
Randomised practices	44 IG: 22 CG: 22	359 IG: 181 CG: 178	262 IG1: 87 IG2: 87 CG: 88
Included patients (n)	NI	3,904	NI
Intervention group (IG)	Behaviour change via outreach visits from a content expert and a behaviour change expert	Electronic DST comprising a comprehensive drug review to support general practitioners in deprescribing potentially inappropriate and non-evidence-based drugs.	IG1: Educational newsletter plus feedback on prescribing safety data IG2: Educational newsletter and feedback, with an added theory-informed behavioural change component
Comparator group (CG)	No intervention	No intervention	Educational newsletter + support for searching
Primary endpoint(s)	Provide personalised nutrition advice, provide ongoing education, provide personalised advice on physical activity, prescribe additional antihypertensive drugs, prescribe additional therapy for the management of glycaemic control, examine feet yourself and/or referring	The primary outcome was the composite of unplanned hospital admission or death by 24 months.	A binary composite measuring the proportion of patients, particularly at risk of an adverse event, from the specified prescribing of those who received one or more high-risk prescriptions defined by the six secondary outcomes
Target group of drugs	Adults	Adults aged 75 years and older	Adults
Efficacy			
(Total) drug prescribing	NI	*Decreased number of prescribed drugs in IG compared to CG, 24 months FU:* IRR: 0.95 (95% CI 0.94 to 0.97; $p<.001$ Sensitive analysis supported this finding.	NI
Specific prescribing	Insulin initiation: Not statistically significant difference at 12-month follow-up (incidence rate ratio 1.18, 95% CI 0.95 to 1.48, $p=.13$) IG: 29 to 37% CG: 31 to 35% Blood pressure: Not statistically significant difference at 12 months follow-up (IRR 1.05, 95% CI 0.96 to 1.16, $p=.29$) IG: 45 to 53% CG: 45 to 50%		*Prevalence of high-risk prescribing at the end of the intervention, after adjustment for the two stratifying variables (health board and third of baseline high risk prescribing:* *Receipt of any high-risk prescription, adjusted odds ratio (95% CI):* IG1 vs. CG: 0.88 (0.80 to 0.96); $p=.007$ IG2 vs. CG: 0.86 (0.78 to 0.95); $p=.002$ *Pre vs. post interventioin* IG1: No immediate level change, but statistically significant and clinically important slope change toward steeper reduction (OR per year 0.87, 95% CI 0.83-0.92).

Author, year	Presseau, 2018 [47]	Rieckert, 2020 [48]	Guthrie, 2016 [49]
Specific prescribing *(continuation)*			IG2: Immediate reduction in high-risk prescribing level (OR 0.96, 95% CI 0.93 to 1.00) and statistically/clinically significant slope change toward steeper reduction (OR per year 0.88, 95% CI 0.84 to 0.93).
Safety			
Rate of return visits/ hospitalisation	NI	*Composite of unplanned hospital admission or death by 24 months:* *IG vs CG:* 871 (44.6%) vs. 944 (48.4%) *ITT-analysis, OR:* 0.88 (95% CI 0.73 to 1.07; p=.19, 997 of 1,953 vs. 1,055 of 1951), n.s.s.	NI
Harms	NI	NI	NI
Economic outcomes			
Prescription costs	*Per patient prescription costs for injectable medication to manage glycaemic control* *Baseline vs. post intervention:* IG: £6,531 (95%CI £6,237 to £6824) vs. £6,081 (95%CI £5,806 to £6,357) CG: £7,205 (95%CI £6,911 to £7,499) vs. £6,570 (95%CI £6,313 to £6,827) Post-intervention log-transformed costs per patient did not differ between groups (p=.25). *Blood pressure prescription costs* *Baseline vs. post-intervention:* IG: £96 (95%CI £92 to £99) vs. £92 (95%CI £89 to £96) CG: £89 (95%CI £83 to £94) vs. £84 (95%CI £78 to £88)	NI	NI
Service use costs	IG vs. CG Mean £24.46 per patient, (95%CI £23.90 to £25.03) vs. £21.61 per patient (95%CI £20.92 to £22.31), p<.001) The absolute difference of £2.85 in costs per patient is relatively small.	NI	NI
Costs of intervention	£1,191 per practice for the research team to develop and deliver	NI	NI
Implementation outcomes			
Use of the intervention	NI	The doctors in the intervention group created 18.7 (SD 8.8) datasets for each participant throughout the study, whereas doctors in the control group created only 12.1 (SD 5.1) datasets.	NI
Feedback from practitioners	NI	NI	NI

Abbreviations: CG … control group; CI … confidence Interval; FU … follow-up; IG … intervention group; IRR … incidence rate ratio; ITT … intention to treat; n … number; NI … no information; p … p-value; UK … United Kingdom; SD … standard deviation; vs. … versus

Table A-9: Description of nudge interventions

Study	Intervention (Nudge)
Antibiotics	
Blair, 2023 [41]	**Chico intervention:** 1. Eliciting explicit carer concerns during consultation, 2. A clinician-focused algorithm to predict the risk of hospitalisation for children with acute cough and respiratory tract infection (RTI) in the following 30 days and 3. A carer-focused personalised printout recording decisions made at the consultation and safety-netting information Clinical decision support tool: ■ Soft pop-up appears when a child presents with potential RTI ■ Uses the STARWAVe algorithm with seven predictors ■ Two predictors (age, asthma history) auto-populate from records ■ Five require clinician input during consultation ■ Categorises hospitalisation risk as elevated, average, or very low ■ Results appear as a small pop-up requiring no action from healthcare professionals ■ The system provides risk assessment through a standardised approach while maintaining normal clinical workflow.

Gulliford, 2019 [42]	**Multicomponent intervention:**
	Webinar: Professionally produced video narrated by a practising general practitioner (GP) in a general practice settingsummarising: importance of antimicrobial resistance, introduction to decision support tools (DSTs), Introduction to antibiotic-prescribing reports, safety of reduced antibiotic prescribing, reduced antibiotic prescribing and patient satisfaction
	Antibiotic prescribing reports: Monthly updated reports on antibiotic-prescribing rates for RTIs:
	■ Number of RTI consultations and antibiotic prescriptions, aggregated monthly
	■ Tabular data and bar charts in PDF format
	■ Year-over-year comparison for the same practice
	■ Standardised template for consistency
	■ Additional Features:
	  ■ Commentary accompanying the data
	  ■ Direct links to DSTs
	Decision support tools: Professionally designed DSTs
	■ Patient/Carer Education Materials covering (e.g. expected illness duration and natural course, self-care recommendations …)
	■ Patient Information Leaflets (printable, e.g. cough and bronchitis, otitis media, sinusitis …)
	■ Prescriber Summary: NICE guidance-based indications for when antibiotics are actually necessary

Meeker, 2016 [43]	Suggested alternatives: ■ Electronic health record (EHR)-based clinical decision support intervention ■ Triggered automatically when acute RTI diagnoses are entered ■ Pop-up message states "Antibiotics are not generally indicated for [this diagnosis]" ■ Presents a list of alternative treatments with streamlined ordering options
	Accountable justification: ■ EHR prompt ■ Appears whenever clinicians attempt to prescribe antibiotics ■ Requires explicit written explanation for the prescribing decision ■ Justification becomes visible as an "antibiotic justification note" in the patient's medical record ■ If no justification is entered, "no justification given" appears in the record ■ Encounters cannot be closed without acknowledging the prompt ■ Clinicians can cancel an antibiotic order to avoid creating a justification note
	Peer comparison: ■ Email-based intervention ■ Regional ranking: Clinicians ranked from highest to lowest inappropriate prescribing rates using EHR data ■ Monthly email feedback with information on prescribing numbers and if clinicians are Top-Performers or not
	Suggested Alternatives + Peer Comparison
	Accountable Justification + Peer Comparison
	Suggested Alternatives + Accountable Justification + Peer Comparison

Study	Intervention (Nudge)
Jeanmougin, 2024 [44]	Feedback Visit: Was carried out by the HIR at the GPs' practice: 1. Providing information about antibiotic resistance, good antibiotic use, and prescription practices; 2. Giving feedback based on individual, regional, and national antibiotic prescription rates; and 3. Providing an information leaflet about the appropriate antibiotic treatment for cystitis and tonsillitis
	CDST-based group: The intervention was carried out by the regional HIR at the GPs' practice and consisted of: 1. providing information about antibiotic resistance, good antibiotic use, and prescription practices; 2. giving feedback based on individual, regional, and national antibiotic prescription rates; and 3. providing a presentation on how to use the CDST in the treatment of cystitis and tonsillitis. 4. The user selects the pathology (not limited to tonsilitis or urinary tract infections), and the tool suggests a therapeutic strategy adapted to French national recommendations.
Schwartz, 2024 [51]	Adjusted data and harms information[13] ■ *Case-mix adjusted group:* Letter standardised their antibiotic prescribing rate using hierarchical regression modelling, which incorporated their number of patient visits per year, as well as patient age, sex, socioeconomic status, comorbidities, and practice setting. On the letter's first page, it was emphasised to physicians that their data were adjusted to represent a fair comparison to physicians with similar patients and practice characteristics. ■ *Unadjusted data group:* received feedback on their raw antibiotic prescribing rate compared with that of their peers. ■ *Harms messaging group:* included an infographic highlighting the frequency of side effects and harms associated with antibiotics. This infographic highlighted the 30% risk of side effects from antibiotic use, the doubling of bacterial resistance rates, and predicted rising mortality from drug resistant infections in the future ■ *Non-harms group:* only received an infographic on the lack of benefits from unnecessary antibiotic prescribing.
Opioids	
Dun, 2023 [50]	Individualised peer comparison report intervention: *Report Components:* ■ Cover letter: Co-signed by the Pharmacy Quality Alliance and the Pain Expert Committee (PEC), explaining purpose and educational guidance ■ Individual identification: Surgeon's name and the National Provider Identifier ■ Measurement definition: Clear explanation of metrics used ■ Visual benchmarking: Bar graph showing national distribution of surgeons' opioid prescribing patterns *Color-coded Performance Indicators:* ■ Green: Recommended range (0-10 tablets) ■ Red: Outlier prescribing (>10 tablets) ■ Visual emphasis: Red arrow highlighting the surgeon's percentile position ■ National benchmark: Average displayed in red box *Expert support:* Contact information for PEC experts provided
Kreamer, 2022 [45]	Alert group: When triggered by an opioid prescription during a qualifying visit, the alert contained a guideline with a short checklist of recommendations 1. to check the state's prescription drug monitoring program. 2. assess risk factors for opioid-related harms (e.g., history of substance use disorder, history of uncontrolled mental health problems, benzodiazepine use); 3. avoid extended-release or long-acting opioids; 4. use a low dose of immediate-release opioid for a short period (3-7 days); consider nonopioid management, such as acetaminophen, nonsteroidal anti-inflammatory drugs, and physical therapy
	Comparison group: Clinicians in the comparison group received the previously described EHR guideline as well as monthly feedback via email regarding initial opioid prescriptions for acute pain, adherence to safe opioid-prescribing guidelines, and the proportion of patients who received opioids for acute pain who transitioned to treatment with long-term opioid therapy (>3 months) compared with other clinicians.
	All interventions combined

[13] For result reporting, the four intervention groups (case-mix adjusted feedback, harms messaging, neither intervention, or both interventions) were analysed as a single combined group versus the control group; therefore, we used the combination of these categories for categorisation process.

Study	Intervention (Nudge)
Navathe, 2022 [46]	Individual audit feedback: The individual audit feedback intervention was implemented by informing clinicians that the health system was reviewing opioid prescriptions with a high number of pills and showing them how many of their prescriptions during the previous month were for thirty or more pills. This was accompanied by a message acknowledging that some of these prescriptions could be appropriate, but that the clinicians should prescribe the minimum clinically necessary number of opioid pills to maximise patient safety
	Peer comparison feedback: informing clinicians of two aspects of their opioid prescribing during the prior three months relative to that of their practice site peers: ■ the mean number of pills per opioid prescription and ■ The proportion of encounters with an opioid prescription.
	A combination of both
Other drugs	
Presseau, 2018 [47]	Behavioural change-focused outreach intervention: ■ Dual expertise team: Content expert + behaviour change expert ■ Duration: 90-minute dedicated team sessions ■ Behaviour selection: Practice teams chose targeted clinical behaviours matching their roles ■ Performance gap analysis: Compared personal estimates of current vs. intended performance levels ■ Barrier identification: Systematically identified obstacles to behaviour change ■ Solution development: Created "if-then" action plans to overcome identified barriers ■ Further components: ▪ created with diabetes patients to pre-identify common barriers and solutions ▪ Short videos with trained actors showing: ▪ Practice-based patient-clinician interactions ▪ Common barriers (e.g., initiating insulin, providing physical activity advice) ▪ Practical solutions for barrier management
Rieckert, 2020 [48]	Electronic decision support tool: The intervention consisted of a computerised decision support tool providing a comprehensive drug review generated from patient data recorded in the electronic case report form. It provides a check of the indications for current drugs based on recorded diagnoses; a summary of measurement results with alerts; recommendations about amending current drugs according to best available evidence; advice on dosage adjustment in renal malfunction; alerts for potentially harmful drug-drug interactions; warnings for possible contraindications; dose warnings; and a table listing each current drug and the associated degree of risk for nine common adverse drug reactions
Guthrie, 2016 [49]	Educational newsletter + peer comparison feedback on prescribing benchmarked rate sent from the NHS Scotland Information Services Division
	Educational newsletter + peer comparison feedback and one-page theory-informed behavioural change component sent from the NHS Scotland Information Services Division

Abbreviation: CDST … clinical decision support tool; GP … general practitioner, e.g. … exempli gratia; EHR … electronic health record; NHS … national health service; PEC … Pain Expert Committee; RTI … respiratory tract infection

Table A-10: ROB2 of cluster randomised controlled trials for efficacy and safety endpoints on antibiotic prescriptions

Trial	Endpoints	Bias arising from the randomisation process	Bias arising from the timing of identification or recruitment	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Efficacy								
Blair, 2023 [41]	Total prescribing	Low	Low	Some concerns*	Low	Low	Low	Some concerns
Gulliford, 2019 [42]	Total prescribing	Low	Some concerns♦	Some concerns*	Low	Low	Low	Some concerns
	Specific prescribing	Low	Some concerns♦	Some concerns*	Low	Low	Low	Some concerns
Jeanmougin, 2024 [44]	Total prescribing	Low	Low	Some concerns*	Low	Low	Low	Some concerns
	Specific prescribing	Low	Low	Some concerns*	Low	Low	Low	Some concerns
Meeker, 2016 [43]	Total prescribing	Low	Low	Some concerns*	Low	Low	Low	Low
	Specific prescribing	Low	Low	Some concerns*	Low	Low	High risk †	High risk
Safety								
Blair, 2023 [41]	Hospitalisation/return visits	Low	Low	Some concerns*	Low	High‡	Low	High
	Harms	Low	Low	Some concerns*	Low	High‡	Low	High
Gulliford, 2019 [42]	Harms	Low	Some concerns♦	Some concerns*	Low	Low	Low	Some concerns
Meeker, 2016 [43]	Hospitalisation/return visits	Low	Low	Some concerns*	Low	Low	Low	Some concerns

Notes:

♦ *Bias arising from the timing of identification or recruitment was assessed as some concerns because of uncertainties regarding whether participants were identified and recruited prior to cluster randomisation.*

* *Bias due to deviation from intended intervention was assessed as some concerns since participants were aware that they were in a trial and in which intervention group they were clustered.*

† *Bias in the selection of the reported result arising from multiple eligible analyses of the data.*

‡ *Bias in the measurement of the outcome for harms was assessed as high, due to self-reporting of the outcome from each practice.*

Table A-11: ROB2 of individual randomised controlled trials for efficacy endpoints on antibiotic prescriptions

Trial	Endpoints	Bias arising from the randomisation process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Efficacy							
Schwartz, 2024 [51]	Total prescribing	Low	Some concerns*	Low	Low	Some concerns†	Some concerns
	Specific prescribing	Low	Some concerns*	Low	Low	Some concerns†	Some concerns

Notes:

* *Bias due to deviation from intended intervention assessed as some concerns due to missing information if participants were aware that they were in a trial and in which intervention group they were clustered.*

† *Bias in the selection of the reported results was assessed as some concerns, because in the reporting of results, the different intervention groups were compared collectively against the control group rather than individually.*

Table A-12: ROB2 of cluster randomised controlled trials for efficacy endpoints on opioid prescriptions

Trial	Endpoints	Bias arising from the randomisation process	Bias arising from the timing of identification or recruitment	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Efficacy								
Kraemer, 2022 [45]	Total prescribing	Some concerns*	Low	Low	Low	Low	Low	Some concerns
	Specific prescribing	Some concerns*	Low	Low	Low	Low	High†	High
Navathe, 2022 [46]	Total prescribing	Low	Low	Low	Low	Low	Low	Low

Notes:

* *Bias arising from the randomisation process due to missing information on allocation sequence concealment.*

† *Bias in the selection of the reported result arising through multiple eligible analyses of the data.*

Table A-13: ROB2 of individual randomised controlled trials for efficacy endpoints on opioid prescriptions

Trial	Endpoints	Bias arising from the randomisation process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Efficacy							
Dun [50]	Total prescribing	Low	High*	High†	Low	Low	High

Notes:

** Bias due to deviation from the intended intervention is assessed as high risk because there is missing information for all domains.*

† Bias due to missing outcome data is assessed as high risk because of the significant loss to follow-up (Intervention:158/245 vs. Control: 151/244).

Table A-14: ROB2 of cluster randomised controlled trials for efficacy and safety endpoints on other medication prescriptions

Trial	Endpoints	Bias arising from the randomisation process	Bias arising from the timing of identification or recruitment	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Efficacy								
Presseau, 2018 [47]	Total prescribing	Low	Low	Low	Low	Low	Low	Low
Rieckert, 2020 [48]	Total prescribing	Low	Low	Low	Low	Low	Low	Low
Safety								
Rieckert, 2020 [48]	Hospitalisation/rate of return visits	Low	Low	Low	Low	Low	Low	Low

Table A-15: ROB2 of individual randomised controlled trials for efficacy endpoints on other medication prescriptions

Trial	Endpoints	Bias arising from the randomisation process	Bias due to deviations from intended interventions	Bias due to missing outcome data	Bias in measurement of the outcome	Bias in selection of the reported result	Overall risk of bias
Efficacy							
Guthrie, 2016 [49]	Specific prescriptions	Low	Low	Low	Low	Low	Low

Table A-16: Survey Questionnaire adopted and translated from German to English

Survey
Peer comparison: The nudging concept of peer comparison was used most frequently and works as follows: Email-based feedback interventions that inform doctors of their prescribing performance in comparison to colleagues (e.g. ranking-based feedback with top performers vs. non-top performers or information on how many tablets were prescribed on average in comparison to colleagues). In some studies, peer comparison was combined with additional components, e.g.: Individual audit feedback: Clinicians were informed about their prescriptions in the previous month, and the need for minimum dosages to maximise patient safety was emphasised. or Colour-coded performance indicators: a visual traffic light system with green indicators for recommended prescription quantities (0-10 tablets) and red markings for outlier prescriptions (>10 tablets), supplemented by a red arrow to highlight the prescribers' percentile position and a red box with the national average value. or Educational newsletter: The newsletter describes specific high-risk prescribing practices and recommends that practices systematically review patients at potential risk. or Harm notifications: Infographic showing the frequency of side effects and harm caused by antibiotics.
Question 1: To what extent would it be possible, in your view, to use this noodle in Austria? *Question 2: What implementation barriers would there be in introducing this approach?* *Question 3: What facilitating factors do you see in Austria concerning the implementation of the nudge above?* *Question 4: How do you assess the acceptance of this nudge among doctors?*
Accountable justification: The nudge for mandatory prescription justification (using antibiotics as an example) is structured as follows: ■ Prompt in the digital patient record ■ Always appears when clinicians attempt to prescribe antibiotics ■ Requires an explicit written justification for the prescription decision ■ The justification is stored as a visible 'antibiotic justification note' in the patient record ■ If no justification is entered, 'no justification provided' appears in the file ■ Patient contacts cannot be completed without confirming the prompt ■ Clinicians can cancel the antibiotic prescription to avoid creating a justification note
Question 1: To what extent would it be possible, in your view, to use this noodle in Austria? *Question 2: What implementation barriers would there be in introducing this approach?* *Question 3: What facilitating factors do you see in Austria concerning the implementation of the nudge above?* *Question 4: How do you assess the acceptance of this nudge among doctors?*
Clinical Decision Support System: This intervention utilises computer-assisted decision support (e.g., embedded guidelines, comprehensive drug evaluation, and warnings) to optimise prescribing practices, although the doctor still makes the final decision on which medication to prescribe.
Question 1: To what extent would it be possible, in your view, to use this noodle in Austria? *Question 2: What implementation barriers would there be in introducing this approach?* *Question 3: What facilitating factors do you see in Austria concerning the implementation of the nudge above?* *Question 4: How do you assess the acceptance of this nudge among doctors?*
Educational work/awareness-raising work: Representatives of the health insurance company conducted this intervention in the general practitioners' surgeries. It consisted of: ■ Providing information on antibiotic resistance, proper antibiotic use and prescribing practices. ■ Providing feedback based on individual, regional and national antibiotic prescriptions. ■ Providing an information sheet on appropriate antibiotic treatment for cystitis and tonsillitis.
Question 1: To what extent would it be possible, in your view, to use this noodle in Austria? *Question 2: What implementation barriers would there be in introducing this approach?* *Question 3: What facilitating factors do you see in Austria concerning the implementation of the nudge above?* *Question 4: How do you assess the acceptance of this nudge among doctors?*

Survey
Multicomponent interventions: These nudges consist of several components, some of which have already been mentioned above. 1. Nudge: Alert + justification + peer comparison a. Alert: A guideline-based alert with recommendations was activated for opioid prescriptions. b. Justification: Mandatory free-text justification for each prescription. c. Peer comparison: Monthly email feedback. or 2. Nudge: Webinar + prescription reports + decision aids a. Webinar: Professionally produced video (content, e.g. significance of antibiotic resistance, introduction to decision aids, introduction to antibiotic prescription reports, etc.). b. Antibiotic prescription reports: Monthly updated reports (no peer comparison) c. Decision aids: Professionally designed decision support tools.
Question 1: To what extent would it be possible, in your view, to use this noodle in Austria? *Question 2: What implementation barriers would there be in introducing this approach?* *Question 3: What facilitating factors do you see in Austria concerning the implementation of the nudge above?* *Question 4: How do you assess the acceptance of this nudge among doctors?*

Abbreviation: e.g. … exempli gratia

HTA Austria
Austrian Institute for
Health Technology Assessment
GmbH