Exploring Moderators of Mobile-Assisted Language Learning Effect on Self-Directed Learning: A Meta-Analysis and Meta-Regression

Abstract

Despite numerous meta-analyses on mobile-assisted language learning (MALL), no study has synthesized research on comparison conditions and moderators of self-directed learning (SDL) in MALL. This study analyzed 27 primary studies published between 2009 and 2021, involving 1,964 participants. The findings suggest that the effect of SDL in MALL varies across conditions, ranging from small (g = .40) in MALL minus feature (MMF) to large (g = .88) in paper-based learning (PBL). Seven moderators impact the MALL effect on SDL, including application type, assessment type, device type, language competency, mother tongue, target language, and target language skills. The article concludes with implications for app creators, practitioners, and researchers.

Objectives

Self-directed learning (SDL) is independent learning where students take ownership of their goals and management (Biwer et al., 2021; Karatas & Arpaci, 2021; Mathur et al., 2022; Morris, 2019). It is grounded in self-determination theory (SDT), suggesting choices drive actions (Deci & Ryan, 1985, p. 38). SDL allows learners to be autonomous, competent, and connected as they assess progress, identify needs, and optimize outcomes (Biwer et al., 2021; Mathur et al., 2022).

SDL has informed numerous studied in MALL literature (e.g., Guskaroska, 2019; García Botero et al., 2021). Some studies have found benefits of language learning apps like GBoard and Duolingo for independent learning (Guskaroska, 2019; García Botero et al., 2021). These studies highlight the enhanced opportunities for self-directed learning, such as immediate feedback, which leads to greater gains (Guskaroska, 2019; García Botero et al., 2021). However, exploring effects and moderators of SDL in MALL as contrasted to different comparison conditions has been overlooked, potentially obscuring our understandings of SDL in MALL efficacy (Mayer, 2015). To address this gap, the present study draws on SDT and Tsai and Tsai's frameworks to investigate the impact of MALL on SDL, considering variations in comparison conditions and moderators. The following research questions guided the present study:

1. What is the effect of SDL in MALL compared to computer-based learning (CBL), MALL minus experimental feature (MMF), and paper-based learning (PBL)?
2. Do any variables moderate the impact of SDL in MALL in each comparison condition?

Theoretical Framework

Self-Determination Theory

SDT has influenced research for nearly 60 years, highlighting autonomy, competence, and relatedness as psychological needs for self-determined motivation (Deci et al., 1991). When learners have comparison and feel confident and connected, they make progress (La Guardia, 2009; Ntoumanis et al., 2021; Reeve, 2012). SDT suggests that fulfilling these needs motivates all students (Cormack et al., 2020). SDT serves as a framework for exploring MALL and self-directed learners' outcomes (Mendiola et al., 2015; Choi et al., 2014).

SDT is well-positioned to serve as a framework for investigating MALL characteristics associated with self-directed learners' outcomes (Mendiola et al., 2015; Choi et al., 2014). For example, automated or tutor-provided feedback and assessment features in MALL applications

inform students of their immediate and long-term progress, providing for self-monitoring, self-regulation, and self-initiation. These features have implications for competence support (Cormack et al., 2020; Nikou & Economides, 2021) as well as for autonomy and relatedness support in SDL contexts (Karatas & Arpaci, 2021; Mathur et al., 2022).

Tsai's (2018) Framework

Analyzing existing research literature on games for learning, Mayer's (2015) identified three high-need areas of research to guide the field. The first is seeking to understand which specific game features could improve academic outcomes in game-based learning contexts (i.e., examining the effectiveness of value-added components, such as feedback). The second is exploring cognitive consequences of using off-shelf digital games (e.g., examining Tetris' impacts on the development of spatial cognition skills). And the third is comparing the effectiveness of game-based vs. traditional (e.g., computer slides) media learning.

Tsai and Tsai (2018) adapted Mayer's (2015) guidelines into a framework for categorizing primary game-based learning studies under three control conditions. The first compares digital games with paper-based learning. The second compares the effectiveness of using digital games with (plus) vs. without (minus) an extra, value-added feature. The final condition is media comparison (i.e., examining whether students learn the same information more effectively using mobile devices vs. traditional media (e.g., computer slides).

Applying Tsai and Tsai's (2018) framework to the current MALL context, this meta-analysis classifies primary studies into three conditions. The first condition includes studies that compare MALL to CBL. The second condition contrasts MALL plus feature with MALL minus feature (MMF). The final condition includes research comparing MALL to PBL. Table 1 summarizes the three conditions.

Method

Data Sources

This meta-analysis integrated findings from multiple independent studies using pre-defined selection criteria (see Appendix A). A comprehensive literature search was conducted to identify relevant studies on SDL in MALL. A total of 27 studies were selected. Figure 1 reports the results of the literature search at each step.

Data Coding

Data coding involved identifying comparison conditions (PBL, CBL, or MMF) and moderators based on MALL, language acquisition, and SDT literature. Tables 1 and 2, respectively, outline the study coding framework and list the moderators of interest to the present study.

Analytic Approach

Effect sizes (ES) were calculated using Hedge's g as the ES metric. A random-effects model was chosen due to heterogeneity in study contexts. Moderation analysis involved subgroup analysis and adjusted R-squared to identify moderators responsible for heterogeneity in the results. Robust variance estimation was used to handle dependencies in effect sizes. Publication bias was assessed using funnel plots and Rosenthal's fail-safe N test.

Results

This meta-analysis synthesized 27 studies published between 2009 and 2021 with 1,964 participants to assess MALL's effect on SDL under varying comparison conditions. It aimed to identify condition-specific moderators. Findings are organized by research questions.

RQ1: What is the effect of MALL on SDL as contrasted to three comparison conditions (CBL, MMF, and PBL)?

The findings (Table 3) revealed significant and positive differences between MALL and two comparison conditions. As contrasted to MMF, MALL showed a small effect (g = .40), while as contrasted to PBL, MALL showed a medium-to-large effect (g = .88). The CBL condition was excluded from the analysis because it did not meet the minimum requirement of two studies (Valentine et al., 2010; Goh et al., 2016) to calculate an aggregate effect size.

Heterogeneity was observed between comparison conditions: Q (6) = 21.46, $p < .05$, I^2 = 65.01 for MMF and Q (25) = 614.25, $p < .05$, I^2 = 86.45 for PBL. Figures 2 and 3 indicated potential publishing bias, but Rosenthal's fail-safe N test revealed no significant effect of the potential publication bias on SDL effect sizes in each comparison condition.

RQ2: What variables, if any, moderate MALL impacts on SDL in each comparison condition?

The results of the random-effects model in Table 3 showed that the studies included in both MMF (I^2 = 65.01) and PBL (I^2 = 86.45) conditions were heterogeneous. To examine probable reasons for heterogeneity at the subcategory and moderator levels, subgroup analysis and univariate and multivariate meta-regression analyses were performed.

Significant Moderators

Table 4 shows that application type, assessment type, language proficiency, mother tongue, target language, and target language skills significantly impact MALL effectiveness on SDL as contrasted to both MMF and PBL comparison conditions. Subgroup analysis reveal that the variation in MALL's impact on SDL is attributed to differences among subcategories of each moderator.

Nonsignificant Moderators

Table 5 shows that among thirteen moderators, only publication type in MMF and PBL conditions did not have a significant effect. The absence of differences among publication type subcategories in this study suggests no influence of publication bias.

Moderators Varying Based on Conditions

Table 6 reveals that as contrasted to the MMF comparison condition, feedback, intervention duration, and learning context did not significantly impact MALL's effect on SDL. However, as contrasted to the PBL comparison condition, all three factors had a significant influence.

This suggests that the comparison condition can modify or contribute to detecting moderator effects. Considerations include stronger similarity in MMF experiences compared to PBL due to device usage differences. Additionally, certain moderator subcategories are available in only one comparison condition, making direct comparison challenging. The study identifies the presence and statistical significance of feedback types in respective conditions rather than their relative effectiveness.

Univariate and Multivariate Meta-Regression Analysis

In this study, the univariate meta-regression analysis (Table 7) showed no single independent variable that could explain the variability in the MMF condition. However, in the PBL condition (Table 8), device type and target language accounted for 23% and 12% of the variability, respectively, in the univariate analysis. Due to the high heterogeneity (86%) in PBL studies, a multivariate meta-regression analysis (Table 9) was conducted. The best model, which included application type, assessment type, device type, language proficiency, learning context, and mother tongue, accounted for 92% of the variability.

Study Significance

Existing research (e.g., García Botero et al., 2021; Liakin et al., 2017) highlights the positive impacts of SDL in MALL on student learning outcomes. However, no prior

meta-analyses have utilized Tsai and Tsai's (2018) framework to examine SDL effects in MALL across comparison conditions. By utilizing Tsai and Tsai's framework, this study addresses the gap in understanding the effect of SDL in MALL across three comparison conditions (CBL, MMF, PBL). The findings will benefit researchers, educators, app developers, and learners, informing the development of SDL educational apps and further inquiry into meeting learners' psychological needs.

In particular, the findings suggest that the influence of MALL on SDL varies depending on comparison conditions and factors such as assessment type, feedback, and application type. The study highlights the importance of assessment and feedback as competence-supportive practices, aligning with the Self-Determination Theory and emphasizing the need for learners to recognize their progress and areas for improvement. Consequently, app creators, educators, and researchers are encouraged to consider these factors and their impact on student learning outcomes more closely.

For educational app creators, the study emphasizes the value of incorporating assessment and feedback features that inform students of their progress. Additionally, educators interested in promoting student autonomy through mobile devices may find SDL to be a viable option for supporting and fostering student learning.

From a research perspective, this study identifies gaps in both primary and meta-analytic studies on MALL, presenting opportunities for future research. Specifically, more primary studies are needed with younger learners, in second language settings, and in formal learning environments. Furthermore, more primary studies comparing MALL with computer-based learning on SDL are required. The study also highlights the importance of investigating the impact of feedback given through mobile devices on SDL, an area that has been largely unexplored in prior meta-analyses.

Overall, this study provides valuable insights into the impact of SDL in MALL and identifies avenues for further research to enhance our understanding of the relationship between comparison conditions, condition-specific moderators (e.g., feedback), and student learning outcomes.

References

Studies that were used in the analysis are denoted in the references with asterisks.

*Ali, A. Z. M., Segaran, K., & Hoe, T. W. (2015). Effects of verbal components in 3D talking-head on pronunciation learning among non-native speakers. *Journal of Educational Technology & Society, 18*(2), 313-322. https://www.learntechlib.org/p/158893/

*Azabdaftari, B., & Mozaheb, M. A. (2012). Comparing vocabulary learning of EFL learners by using two different strategies: Mobile learning vs. flashcards. *The Eurocall Review, 20*(2), 47-59. https://doi.org/10.1504/IJMLO.2012.050050

*Bakay, Ş. (2017). *Investigating the effectiveness of a mobile device supported learning environment on English preparatory school students' vocabulary acquisition* (Doctoral dissertation, Middle East Technical University, Ankara). https://open.metu.edu.tr/handle/11511/26543

*Baleghizadeh, S., & Oladrostam, E. (2010). The effect of mobile assisted language learning (MALL) on grammatical accuracy of EFL students. *Mextesol Journal, 34*(2), 1-10. https://www.mextesol.net/journal/index.php?page=journal&id_article=50

*Basal, A., Yilmaz, S., Tanriverdi, A., & Lutfiye, S. (2016). Effectiveness of mobile applications in vocabulary teaching. *Contemporary educational technology, 7*(1), 47-59. https://doi.org/10.30935/cedtech/6162

*Basoglu, E. B., & Akdemir, O. (2010). A comparison of undergraduate students' English vocabulary learning: Using mobile phones and flash cards. *Turkish Online Journal of Educational Technology-TOJET, 9*(3), 1-7.

*Bieńkowska, I., Klimczok, A. Polok, K., & Modrzejewska, J. (2021). Use of mobile assisted language learning (MALL) in teaching vocabulary to ESP students. *The International Journal of Research in Teacher Education, 12*(3), 81-95. https://ijrte.penpublishing.net/makale/2614

Biwer, F., Wiradhany, W., Oude Egbrink, M., Hospers, H., Wasenitz, S., Jansen, W., & De Bruin, A. (2021). Changes and adaptations: How university students self-regulate their online learning during the COVID-19 pandemic. *Frontiers in psychology, 12*, 642593. https://doi.org/10.3389/fpsyg.2021.642593

Burston, J. (2014). The reality of MALL: Still on the fringes. CALICO Journal, 31(1), 103–125. https://doi.org/10.11139/cj.31.1.103-125

*Chakir, M. (2018). *The integration of mobile phones in EFL contexts: Using Messenger applications to learn English vocabulary* (Master's thesis, Southern Illinois University at Edwardsville). https://www.proquest.com/dissertations-theses/integration-mobile-phones-efl-contexts-using/docview/2054017512/se-2

*Chen, C. M., Chen, L. C., & Yang, S. M. (2019). An English vocabulary learning app with self-regulated learning mechanism to improve learning performance and motivation. *Computer Assisted Language Learning, 32*(3), 237-260. https://doi.org/10.1080/09588221.2018.1485708

Chen, Z., Chen, W., Jia, J., & An, H. (2020). The effects of using mobile devices on language learning: A meta-analysis. *Educational Technology Research and Development, 68*(4), 1769-1789. https://doi.org/10.1007/s11423-020-09801-5

Choi, J., Noh, G. Y., & Park, D. J. (2014). Smoking cessation apps for smartphones: content analysis with the self-determination theory. *Journal of medical Internet research, 16*(2), e3061. https://doi.org/10.2196/jmir.3061

Cormack, J., Rowell, K., & Postăvaru, G. I. (2020). Self-determination theory as a theoretical

framework for a responsive approach to child feeding. *Journal of nutrition education and behavior*, *52*(6), 646-651. https://doi.org/10.1016/j.jneb.2020.02.005

Cornell, J., & Mulrow, C. (1999). Meta-Analysis. In A. Herman & M. Gideon (Eds.), Research mythology in the social, behavioral, and life sciences (pp. 285–323). SAGE Publications. https://doi.org/10.1177/1362168820913998

*Dağdeler, K. O., Konca, M. Y., & Demiröz, H. (2020). The effect of mobile-assisted language learning (MALL) on EFL learners' collocation learning. *Journal of Language and Linguistic Studies*, *16*(1), 489-509. https://doi.org/10.17263/jlls.712891

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior.* Plenum. https://doi.org/10.1007/978-1-4899-2271-7

Deci, E. L., Vallerand, R. J., Pelletier, L. G., & Ryan, R. M. (1991). Motivation in education: The self-determination perspective. *Educational Psychologist*, *26*(3&4), 325–346. https://doi.org/10.1080/00461520.1991.9653137

*García Botero, G., Botero Restrepo, M. A., Zhu, C., & Questier, F. (2021). Complementing in-class language learning with voluntary out-of-class MALL. Does training in self-regulation and scaffolding make a difference? *Computer Assisted Language Learning*, *34*(8), 1013-1039. https://doi.org/10.1080/09588221.2019.1650780

*Gharehblagh, N. M., & Nasri, N. (2020). Developing EFL elementary learners' writing skills through mobile-assisted language learning (MALL). *Teaching English with Technology*, *20*(1), 104-121. https://eric.ed.gov/?id=EJ1242657

Goh, J. X., Hall, J. A., & Rosenthal, R. (2016). Mini meta-analysis of your own studies: Some arguments on why and a primer on how. *Social and Personality Psychology Compass*, *10*(10), 535-549. https://doi.org/10.1111/spc3.12267

*Guskaroska, A. (2019). ASR as a tool for providing feedback for vowel pronunciation practice (Master's thesis, Iowa State University). https://dr.lib.iastate.edu/entities/publication/b630e977-d5ca-4d0a-a89a-4602f291041e

Harrer, M., Cuijpers, P., Furukawa, T. A., & Ebert, D. D. (2019). Doing meta-analysis with R: A Hands-On guide. https://doi.org/10.1201/9781003107347

*Hayati, A., Jalilifar, A., & Mashhadi, A. (2013). Using short message service (SMS) to teach English idioms to EFL students. *British journal of educational technology*, *44*(1), 66-81. https://doi.org/10.1111/j.1467-8535.2011.01260.x

Hepplestone, S., Glover, I., Irwin, B., & Parkin, H. (2016). Setting out the role of feedback in the assessment process through both the student and tutor perspective. *Practitioner Research in Higher Education*, *10*(1), 81-90. https://eric.ed.gov/?id=EJ1129940

Jang, E. E., & Sinclair, J. (2021). Diagnostic assessment in language classrooms. In *The Routledge handbook of language testing* (pp. 187-205). Routledge. https://www.taylorfrancis.com/chapters/edit/10.4324/9781003220756-15/diagnostic-assessment-language-classrooms-eunice-eunhee-jang-jeanne-sinclair

Karatas, K., & Arpaci, I. (2021). The role of self-directed learning, metacognition, and 21st century skills predicting the readiness for online learning. *Contemporary Educational Technology*, *13*(3). https://doi.org/10.30935/cedtech/10786

*Kondo, M., Ishikawa, Y., Smith, C., Sakamoto, K., Shimomura, H., & Wada, N. (2012). Mobile assisted language learning in university EFL courses in Japan: Developing attitudes and skills for self-regulated learning. *ReCALL*, *24*(2), 169-187. https://doi.org/10.1017/S0958344012000055

La Guardia, J. G. (2009). Developing who I am: A self-determination theory approach to the establishment of healthy identities. *Educational Psychologist, 44*(2), 90-104. http://dx.doi.org/10.1080/00461520902832350

*Lee, P. (2014, September). Are mobile devices more useful than conventional means as tools for learning vocabulary? *In 2014 IEEE 8th International Symposium on Embedded Multicore/Manycore SoCs* (pp. 109-115). IEEE. https://doi.org/10.1109/MCSoC.2014.24

*Liakin, D., Cardoso, W., & Liakina, N. (2017). The pedagogical use of mobile speech synthesis (TTS): Focus on French liaison. *Computer Assisted Language Learning, 30*(3-4), 325-342. https://doi.org/10.1080/09588221.2017.1312463

Mathur, P., Yucel-Aybat, O., Block, L., & Eisenstein, E. M. (2022). The effect of consumers' implicit theory of personality and product feedback in self-directed consumer contexts. *Personality and Individual Differences*, *190*, 111526. https://doi.org/10.1016/j.paid.2022.111526

Mayer, R. E. (2015). On the need for research evidence to guide the design of computer games for learning. *Educational Psychologist*, *50*(4), 349-353. https://doi.org/10.1080/00461520.2015.1133307

Mendiola, M. F., Kalnicki, M., & Lindenauer, S. (2015). Valuable features in mobile health apps for patients and consumers: content analysis of apps and user ratings. *JMIR mHealth and uHealth*, *3*(2), e4283. https://doi.org/10.2196/mhealth.4283

*Moayeri, M., & Khodareza, M. R. (2020). The effect of mobile-assisted language learning on speaking accuracy of EFL learners. *Technology in Language Teaching & Learning, 2* (1), 22–35. https://doi.org/10.29140/tltl.v2n1.140

Mohamed, A. (2020). Feedback in Computer-Assisted Language Learning: A meta-analysis. *TESL-EJ*, *24*(2), n2. https://eric.ed.gov/?id=EJ1268711

Morris, T. H. (2019). Self-directed learning: A fundamental competence in a rapidly changing world. *International Review of Education*, *65*(4), 633-653. https://doi.org/10.1007/s11159-019-09793-2

*Motallebzadeh, K., & Ganjali, R. (2011). SMS: Tool for l2 vocabulary retention and reading comprehension ability. *Journal of Language Teaching & Research, 2*(5). https://doi.org/10.4304/jltr.2.5.1111-1115

*Motallebzadeh, K., Beh-Afarin, R., & Daliry Rad, S. (2011). The effect of short message service on the retention of collocations among Iranian lower intermediate EFL Learners. *Theory & Practice in Language Studies, 1*(11). https://doi.org/10.4304/tpls.1.11.1514-1520

Nikou, S. A., & Economides, A. A. (2021). A framework for mobile-assisted formative assessment to promote students' self-determination. *Future Internet, 13*(5), 116. https://doi.org/10.3390/fi13050116

Ntoumanis, N., Ng, J. Y., Prestwich, A., Quested, E., Hancox, J. E., Thøgersen-Ntoumani, C., ... & Williams, G. C. (2021). A meta-analysis of self-determination theory-informed intervention studies in the health domain: Effects on motivation, health behavior, physical, and psychological health. *Health Psychology Review*, *15*(2), 214-244. https://doi.org/10.1080/17437199.2020.1718529

*Rahimi, M., & Miri, S. S. (2014). The impact of mobile dictionary use on language learning. *Procedia-Social and Behavioral Sciences*, *98*, 1469-1474. https://doi.org/10.1016/j.sbspro.2014.03.567

Reeve, J. (2012). A self-determination theory perspective on student engagement. In Handbook

of research on student engagement (pp. 149-172). Springer. https://doi.org/10.1007/978-1-4614-2018-7_7

Sung, Y., Chang, K., & Liu, T. (2016). The effects of integrating mobile devices with teaching and learning on students' learning performance: A meta-analysis and research synthesis. *Computers & Education, 94*, 252–275. https://doi.org/10.1016/j.compedu.2015.11.008

Sung, Y., Chang, K., & Yang, J. (2015). How effective are mobile devices for language learning? *A meta-analysis. Educational Research Review*, *16*, 68–84. https://doi.org/10.1016/j.edurev.2015.09.001

*Suwantarathip, O., & Orawiwatnakul, W. (2015). Using Mobile-Assisted Exercises to Support Students' Vocabulary Skill Development. *Turkish Online Journal of Educational Technology-TOJET*, *14*(1), 163-171. https://eric.ed.gov/?id=EJ1057347

*Tabatabaei, O., & Goojani, A. H. (2012). The impact of text-messaging on vocabulary learning of Iranian EFL learners. *Cross-Cultural Communication*, *8*(2), 47-55. http://dx.doi.org/10.3968/j.ccc.1923670020120802.1689

Tsai, Y. L., & Tsai, C. C. (2018). Digital game-based second-language vocabulary learning and conditions of research designs: A meta-analysis study. *Computers & Education, 125*, 345-357. https://doi.org/10.1016/j.compedu.2018.06.020

Valentine, J. C., Pigott, T. D., & Rothstein, H. R. (2010). How many studies do you need? A primer on statistical power for meta-analysis. *Journal of Educational and Behavioral Statistics*, *35*(2), 215-247. https://doi.org/10.3102/1076998609346961

*Wu, Q. (2014). Learning ESL vocabulary with smartphones. *Procedia-Social and Behavioral Sciences*, *143*, 302-307. https://doi.org/10.1016/j.sbspro.2014.07.409

*Wu, Q. (2015). Designing a smartphone app to teach English (L2) vocabulary. *Computers & Education*, *85*, 170–179. https://doi.org/10.1016/j.compedu.2015.02.013

*Wu, Q. (2015). Pulling mobile assisted language learning (MALL) into the mainstream: MALL in broad practice. *PloS One*, *10*(5), e0128762. https://doi.org/10.1371/journal.pone.0128762

*Yousefzadeh, M. (2012). Mobile-based learning vs. paper-based learning and collocation words learning. *Journal of Educational and Instructional Studies*, *2*(3), 216-220. https://www.ajindex.com/dosyalar/makale/acarindex-1423906081.pdf

*Zhang, H., Song, W., & Burston, J. (2011). Reexamining the effectiveness of vocabulary learning via mobile phones. *Turkish Online Journal of Educational Technology-TOJET*, *10*(3), 203-214. https://eric.ed.gov/?id=EJ944968

Appendix A

Selection Criteria

At each level of the screening process, the investigator used the following selection criteria:

- The dependent variable in the primary study must be target language skills.
- The independent variable in the primary study must be MALL.
- MALL application's teaching method in the primary study must be self-directed learning.
- The study must include both the treatment and comparison/comparison conditions.
- The study employs a between-subjects experimental design.
- The study contains enough statistical data to calculate the effect size.
- The study is published in English.

Table 1

Condition Coding

Condition	Experimental Group	Comparison Group
CBL	Students learn through a mobile device	Students learn through CBL
MMF	Students learn through a mobile device with (an) additional experimental feature(s)	Students learn through a mobile device with no additional experimental feature(s)
PBL	Students learn through a mobile device	Students learn through PBL

Table 2

Moderator Description

Moderator	Description
Application Type	Primary studies were used to code for the application type (e.g., Duolingo, GBoard). Investigating if different application types achieve comparable learning outcomes or result in disparate outcomes (Chen et al., 2020) would assist educators, practitioners, and app developers in choosing which applications are best suited for achieving particular learning goals (Sung et al., 2016).
Assessment Type	Primary studies were used to code for the assessment type (audio recording, translation). Documenting learners' progress, assessment is crucial to language learning (Jang & Sinclair, 2021; Li & Zhang, 2021). As a moderator, the influence of assessment type has not yet been investigated, a gap that may be particularly important to address when investigating the effect of MALL on SDL.
Device type	Primary studies were used to code for device type (e.g., smartphone). Despite the fact that device types have been investigated, there is no agreement if device types considerably affects MALL. For instance, Chen et al. (2020) found no statistically significant differences across devices with an opposite result reported in Sung et al. (2016).
Educational Level	Educational levels included: primary, secondary, postsecondary, and mixed categories. Previous meta-analyses (e.g., Chen et al., 2020; Tsai & Tsai, 2018) produced inconsistent findings regarding educational level; the present study extends this work to SDL to generate additional evidence.
Feedback	Feedback is a human or computer-generated post-commentary that identifies the learner's mistakes. It is essential for students to receive feedback. It motivates learners to self-assess their learning (Ada, 2018). According to Hepplestone et al. (2016), as one of the aspects of language acquisition students appreciate feedback the most. SDT

	research has identified feedback as one of the competence-supporting sources. Given this, it is critical to ascertain whether MALL feedback modifies the impact of SDL. In this study, the feedback categories developed from literature included: (a) feedback provided by the application (i.e., the program delivers feedback electronically) and (b) feedback sent via application (i.e., educators or learners use the application to provide feedback).
Intervention Duration	Building on earlier work (Chen et al., 2020), intervention duration included: one week, less than four weeks, less than 10 weeks, and less than 20 weeks.
Language Proficiency	Levels of language proficiency included beginner, beyond-beginner (intermediate-to-advanced level), and mixed (study included participants across levels of language proficiency; Chen et al., 2020).
Learning Context	Learning contexts include formal (classroom), informal (home), and mixed (i.e., a combination of formal and informal learning). Tsai and Tsai (2018) findings suggest that students perform better in contexts where they are given fewer instructions and experience less stress. Even though Tsai and Tsai examined a variety of contexts, the generalizability of their findings focused on game-based learning need to be extended to SDL.
Mother tongue	The participants' mother tongue (native language) was coded as described in the original study. Studies with participants who spoke several languages were categorized as mixed (Mohamed, 2020).
Publication Type	Types of publications include articles, conference presentations, dissertations, or master's theses. Because reviewers and editors are more likely to approve and journals are more likely to publish studies with statistically significant findings (Cornell & Mulrow, 1999), it is important to consider the publication type as a moderator.
Research setting	The two main research categories of the research setting include a foreign language (FL) and a second language (SL). The FL requires learning a language other than the country's mother tongue (e.g., learning English in Japan). Learning the language predominant in the community (e.g., learning English in the USA) is referred to as SL. Settings could moderate the effect of MALL (e.g., Chen et al., 2020); whether this finding will hold under the different conditions (MMF, PBL) needs investigation.
Target language	The language that students are learning is the target language (e.g., Spanish, English). Concerning the significance of target language as a moderator, MALL researchers (Burston, 2014; Sung et al., 2015) appear to be in accord. However, the effect

	of the target language in different conditions is not explored. Therefore, this research is necessary to determine whether the target language could moderate the MALL's influence on SDL under various conditions.
Target language skill	The target language skills include grammar, listening, reading, speaking, etc. (Chen et al. (2020).

Table 3

The Effect Size in Each Condition

	MMF	PBL
Model	RE	RE
K	7	26
g	0.40*	0.88*
95% CI	0.02 – 0.78	0.58 – 1.19
p	0.0418	0.0001
Test of heterogeneity		
Q	21.46*	614.25*
df	6	25
I^2%	65.01	86.45
P	0.0015	0.0001
Participants	459	1,505
Classic Fail-safe *N*	45	1,950

Note. *$p < .05$, NR= not reported, *K* = number of studies, *CI* = confidence interval, *df* = degree of freedom., *g*= Hedges' *g, Fail*-safe $N > 5 Nes + 10$

Table 4
The Subgroup Results for Significant Moderators in MMF and and PBL

	MMF		PBL	
Moderator	Effect Size *K/g/95%CI*	Test of Heterogeneity *Q* /I^2/*p*	Effect Size *K/g/95%CI*	Test of Heterogeneity *Q* /I^2/*p*
Application type		*Q* (6) =13.74, I^2 = 86.33, *p* =0.00		*Q* (12) =97.53, I^2 = 88.01, *p* =0.00
3D Talking head	*K*=1, *g*=0.25, *95% CI* [-0.42 - 0.91 0]		0	
ACO			*K*=1, *g*=0.34, *95% CI* [-0.38 - 1.05]	
CollocatApp	0		*K*=1, *g*=0.35, *95% CI* [0.59 - 1.29]	
Duolingo	*K*=3, *g*=-0.7, *95% CI* [-2.26 - 0.8]		*K*=3, *g*=-1.62, *95% CI* [2.43 - 0.81]	
Electronic Dictionary	0		*K*=1, *g*=-0.76, *95% CI* [1.76 - 0.24]	
EVLAPP-SRLM	0		*K*=1, *g*=-1.33, *95% CI* [2.27 - 0.39]	

	Flash Card	0	*K*=1, *g*=-1.52, *95% CI* [2.42 - 0.63]
	GBoard	*K*=1, *g*=0.03, *95% CI* [-0.9 - 0.95]	0
	MeWe	0	*K*=1, *g*=-0.86, *95% CI* [1.84 - 0.12]
	MMS	0	*K*=1, *g*=-1.28, *95% CI* [2.48 - 0.09]
	SMS	0	*K*=8, *g*=-0.6, *95% CI* [1.36 - 0.17]
	SRL	0	*K*=2, *g*=-1.78, *95% CI* [2.57 - 1]
	Text-to-speech	0	*K*=1, *g*=-1.3, *95% CI* [2.46 - 0.15]
	WhatsApp	0	*K*=3, *g*=-0.78, *95% CI* [1.56 - 0.02]
	Word learning	*K*=2, *g*=0.8, *95% CI* [0.33 - 1.26]	*K*=2, *g*=-0.73, *95% CI* [1.56 - 0.1]
Assessment type		*Q* (3) =13.74, I^2 = 65.13, *p* =0.00	*Q* (8) =93.61, I^2 = 83.53, *p* =0.00
	Building a sentence with a new word	0	*K*=1, *g*=0.08, *95% CI* [0.5 - 1.1]

Fill in the blank	0	*K*=2, *g*=0.34, *95% CI* [0.26 - 0.92]
Multiple choice	0	*K*=12, *g*=0.18, *95% CI* [0.25 - 0.61]
Multiple choice and writing	0	*K*=1, *g*=0.12, *95% CI* [0.67 - 0.91]
NR	*K*=3, *g*=-0.24, *95% CI* [-1.82 - 1.34]	*K*=5, *g*=-0.84, *95% CI* [1.29 - 0.39]
Pronouncing words	*K*=1, *g*=0.25, *95% CI* [-0.42 - 0.91]	0
Recording their pronunciation	*K*=1, *g*=0.03, *95% CI* [-0.9 - 0.95]	*K*=2, *g*=-0.42, *95% CI* [1.17 - 0]
Recording their voices (speaking)	0	*K*=1, *g*=0.88, *95% CI* [0.05 - 1.72]
Write a sentence	0	*K*=1, *g*=-0.4, *95% CI* [0.99 - 0.19]
Write down translation	*K*=2, *g*=0.08, *95% CI* [0.33 - 1.26]	0
Write meaning	0	*K*=1, *g*=2.7, *95% CI* [0.87 - 2.54]

Language proficiency		Q (3) =13.74, I^2 = 65.13, p =0.00	Q (2) =12.33, I^2 = 87.67, p =.00
	Beginner	*K*=1, *g*=0.22, *95% CI* [0.22-0.22]	*K*=10, *g*=-0.02, *95% CI* [-0.95 - 0.93]
	Beyond-beginner	*K*=1, *g*=0.55, *95% CI* [0.03 - 11]	*K*=7, *g*=0.49, *95% CI* [0.21 - 0.76]
	Mixed	*K*=1, *g*=0.22, *95% CI* [1.2 - 76]	0
	NR	*K*=3, *g*=-0.25, *95% CI* [-0.91 - 0.42]	*K*=9, *g*=0.03, *95% CI* [0.05 - 0.55]
Mother tongue		Q (3) =13.74, I^2 = 65.13, p =0.00	Q (8) =84.46, I^2 = 87.67, p =0.00
	Arabic	0	*K*=1, *g*=-0.24, *95% CI* [-1.19 - 0.71]
	Chinese	*K*=2, *g*=0.07, *95% CI* [1.43 - 0.24]	*K*=4, *g*=0.01, *95% CI* [-0.58 - 0.58]
	English	0	*K*=1, *g*=-0.34, *95% CI* [-1.38

			- 0.7]
	Japanese	0	*K*=2, *g*=-0.82, *95% CI* [-1.41 - -0.24]
	Macedonian	*K*=1, *g*=-0.77, *95% CI* [-1.64 - 5]	0
	Malay	*K*=1, *g*=-0.55, *95% CI* [-1.12 - 64]	0
	Persian	0	*K*=8, *g*=0.65, *95% CI* [0.09 - 1.22]
	Polish	0	*K*=1, *g*=0.08, *95% CI* [-0.57 - 0.73]
	Spanish	*K*=3, *g*=-0.8, *95% CI* [-1.26 - -0.33]	*K*=3, *g*=-0.66, *95% CI* [-1.28 - -0.04]
	Thai	0	*K*=1, *g*=-0.1, *95% CI* [-0.78 - 0.58]
	Turkish	0	*K*=5, *g*=0.28, *95% CI* [-0.32 - 0.86]
Target language		*Q* (1) =7.92, I^2 = 63.38, *p* =0.00	*Q* (1) =16.01, I^2 = 85.62, *p* =0.00
	English	*K*=4, *g*=0.42, *95% CI* [0.82 - 1.5]	*K*=22, *g*=0.53, *95% CI* [0.19 - 0.89]

French	*K*=3, *g*=-0.66, *95% CI* [1.11 – 9.78]		*K*=4, *g*=-0.69, *95% CI* [1.03 - 0.36]
Target language skills		*Q* (4) =19.82, I^2 = 6.43, *p* =0.00	*Q* (5) =70.22, I^2 = 83.11, *p* =0.00
Listening Comprehension	*K*=1, *g*=-1.21, *95% CI* [-1.21- - 1.21]		*K*=2, *g*=-1.12, *95% CI* [-3.43 - 1.2]
Pronunciation	*K*=2, *g*=0.67, *95% CI* [0.17 - 1.51]		*K*=2, *g*=0.44, *95% CI* [-0.3 - 1.16]
Reading Comprehension	*K*=1, *g*=0.26, *95% CI* [-0.72 - 1.24]		*K*=2, *g*=-0.08, *95% CI* [-0.54 - 89]
Speaking	0		*K*=1, *g*=1.73, *95% CI* [0.92 - 2.53]
Vocabulary	*K*=2, *g*=1.28, *95% CI* [0.53 - 2.03]		*K*=18, *g*=1.01, *95% CI* [0.66 - 1.36]
Writing	*K*=1, *g*=1.21, *95% CI* [0.22 - 2.21]		*K*=1, *g*=0.3, *95% CI* [-0.39 - 38]

Note. 0= A value of "0" in the table indicates that there were no available studies or data for a particular subcategory within a specific variable, under certain conditions, *NR*= not reported, *K* = number of studies, *CI* = confidence interval, *df* = degree of freedom, *g*= Hedges' *g*.

Table 5

The Subgroup Results for Insignificant Moderators in MMF and and PBL

	MMF		PBL	
	Effect Size *K/g/95%CI*	Test of Heterogeneity *Q* /I^2/*p*	Effect Size *K/g/95%CI*	Test of Heterogeneity *Q* /I^2/*p*
Moderator				
Publication type		*Q* (1) =1.38, I^2 = 72.7, *p* =0.2		*Q* (3) =2.19, I^2 = 88.06, *p* =0.53
Article	*K*=2, *g*=0.26, *95% CI* [13 - 0.8]		*K*=23, *g*=0.11, *95% CI* [-0.27 - 0.49]	
Conference Paper	0		*K*=1, *g*=-0.34, *95% CI* [-0.79 - 0.12]	
Dissertation	*K*=1, *g*=-0.52, *95% CI* [1.37 - 0.35]		*K*=1, *g*=-0.09, *95% CI* [-0.58 - 0.75]	
Master's thesis	0		*K*=1, *g*=-0.02, *95% CI* [-0.55 - 0.52]	

Note. 0= A value of "0" in the table indicates that there were no available studies or data for a particular subcategory within a specific variable, under certain conditions, *NR*= not reported, *K* = number of studies, *CI* = confidence interval, *df* = degree of freedom, *g*= Hedges' *g*.

Table 6

The Subgroup Results for The Moderators Varying in their Significance between MMF and and PBL

	MMF		PBL	
	Effect Size *K/g/95%CI*	Test of Heterogeneity *Q* /I^2/*p*	Effect Size *K/g/95%CI*	Test of Heterogeneity *Q* /I^2/*p*
Moderator				
Feedback		*Q* (1) =1.38, I^2 = 72.7, *p* =0.2		*Q* (1) =5.05, I^2 = 87.11, *p* =0.02
By application	*K*=1, *g*=-0.26, *95% CI* [-0.82 - 0.31]		0	
NR	*K*=6, *g*=0.52, *95% CI* [-2.58 - 2.17]		*K*=24, *g*=-0.21, *95% CI* [-2.58 - 2.17]	
Intervention duration		*Q* (3) =2.38, I^2 = 85.63, *p* =0.4		*Q* (2) =19.47, I^2 = 87.19, *p* =0.00
Less than four weeks	*K*=1, *g*=-0.2, *95% CI* [-1.28 - 0.88]		*K*=3, *g*=-0.55, *95% CI* [1.31 - 0.23]	
Less than ten weeks	*K*=1, *g*=0.51, *95% CI* [0.46 - 47]		*K*=14, *g*=0.35, *95% CI* [-0.04 - 0.73]	
Less than twenty weeks	*K*=4, *g*=0.57, *95% CI* [0.3 - 43]		*K*=9, *g*=-0.17, *95% CI* [0.57 - 0.23]	

	One week	*K*=1, *g*=0.22, *95% CI* [-0.76 - 1.2]	
Learning context		*Q* (3) =1.16, I^2 = 75.16, *p* =0.20	*Q* (3) =13, I^2 = 87.7, *p* =0.00
	Formal	*K*=1, *g*=0.01, *95% CI* [0.58 - 0.58]	*K*=4, *g*=0.19, *95% CI* [-1.11 - 1.47]
	Informal	*K*=6, *g*=0.01, *95% CI* [-0.58 - 0.58	*K*=19, *g*=-0.55, *95% CI* [0.89 - 0.2]
	Mixed	0	*K*=3, *g*=-0.13, *95% CI* [0.61 - 0.36]

Note. 0= A value of "0" in the table indicates that there were no available studies or data for a particular subcategory within a specific variable, under certain conditions, *NR*= not reported, *K* = number of studies, *CI* = confidence interval, *df* = degree of freedom, *g*= Hedges' *g*.

Table 7

Univariate Regression Results for Moderators in MMF

Moderator	*Adj* R^2	*RSR*	*p*
Application type	-0.15	0.53	0.59
Assessment type	-0.15	0.53	0.59
Device type	-0.17	0.54	0.60
Feedback	-0.15	0.54	0.68
Intervention duration	-0.83	0.67	0.95
Language proficiency	-0.15	0.53	0.59
Learning context	-0.2	0.55	0.99
Mother tongue	-0.15	0.53	0.59
Publication type	-0.16	0.54	0.68
Target language	0.04	0.49	0.32
Target language skills	0.84	0.20	0.10

Note. * =p < .05, *RSR*= Residual standard error, *Adj* R^2 =Adjusted *R* Square.

Table 8

Univariate Regression Results for Moderators in PBL

Moderator	*Adj* R^2	*RSR*	*p-value*
Application type	0.14	0.77	0.30
Assessment type	0.29	0.70	0.07
Device type	0.23	0.73	0.01
Educational level	-0.13	0.88	0.95
Feedback	-0.04	0.84	0.74
Intervention duration	0.02	0.82	0.33
Language Proficiency	-0.08	0.86	0.90
Learning context	-0.09	0.86	0.93
Mother tongue	0.18	0.75	0.18
Publication type	-0.12	0.87	0.93
Research setting	-0.03	0.84	0.53
Target language	0.12	0.78	0.04
Target language skills	-0.03	0.73	0.07

Note. RSR= Residual standard error, *Adj* R^2 =Adjusted *R* Square.

Table 9

The Summary Model of Application Type, Assessment Type, Device Type, Language Proficiency, Learning Context, and Mother Tongue

Model	*Adj* R^2	RSR	*p*-value
1	0.92	*0.22*	0.02

Note. * =p < .05, *RSR*= Residual standard error, *Adj* R^2 =Adjusted *R* Square.

Figure 1
Flow chart of the literature search

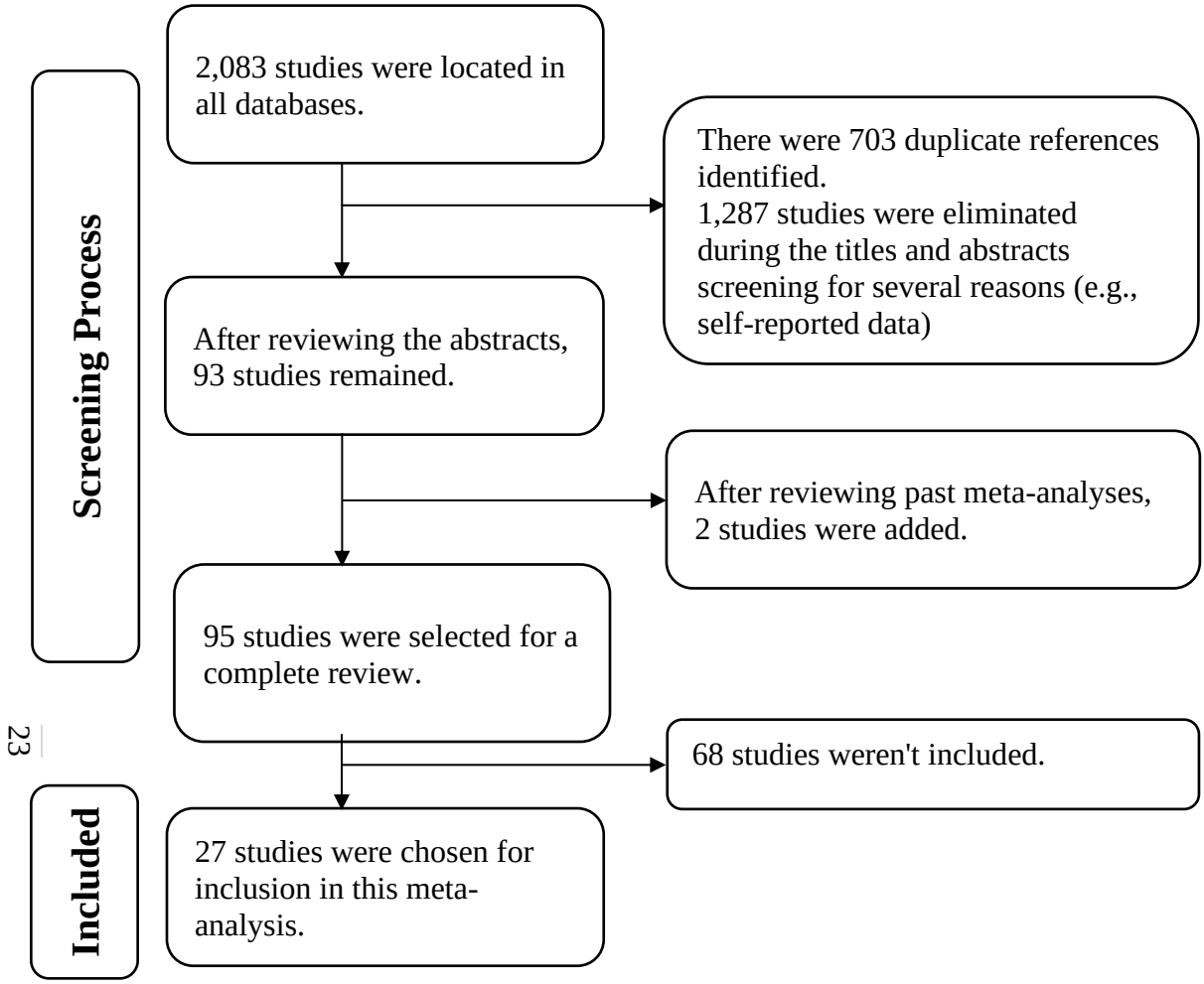

Figure 2
MMF Posttest Funnel Plot

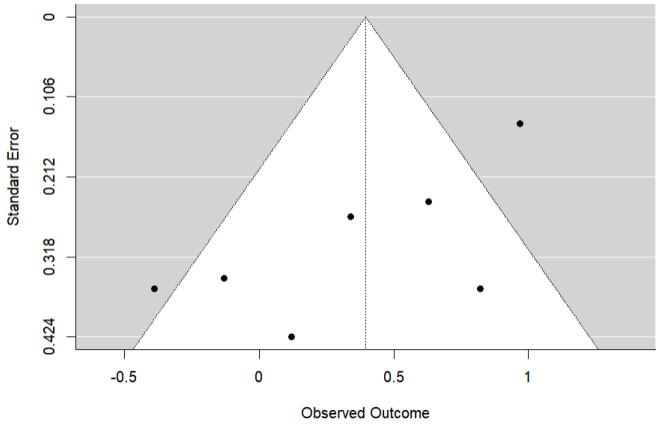

Figure 3
PBL Posttest Funnel Plot