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# Why Did Developers Migrate Android Applications From Java to Kotlin?

Matias Martinez  and Bruno Gois Mateus

**Abstract**—Currently, the majority of apps running on mobile devices are Android apps developed in Java. However, developers can now write Android applications using a new programming language: Kotlin, which Google adopted in 2017 as an official programming language for developing Android apps. Since then, Android developers have been able to: a) start writing Android applications from scratch using Kotlin, b) evolve their existing Android applications written in Java by adding Kotlin code (possible thanks to the interoperability between the two languages), or c) migrate their Android apps from Java to Kotlin. This paper aims to study this last case. We conducted a qualitative study to find out *why* Android developers have migrated Java code to Kotlin and to bring together their experiences about the process, in order to identify the main difficulties they have faced. To execute the study, we first identified commits from open-source Android projects that have migrated Java code to Kotlin. Then, we emailed the developers that wrote those migrations. We thus obtained information from 98 developers who had migrated code from Java to Kotlin. This paper presents the main reasons identified by the study for performing the migration. We found that developers migrated Java code to Kotlin in order to access programming language features (e.g., extension functions, lambdas, smart casts) that are not available with Java for Android development, and to obtain safer code (i.e., avoid null-pointer exceptions). We also identified research directions that the research community could focus on in order to help developers to improve the experience of migrating their Java applications to Kotlin.

## 1 INTRODUCTION

CURRENTLY, Android from Google is the mobile platform used on most smartphones around the world [1]. Traditionally, Android applications were developed using Java programming language. However, in 2017, Google adopted Kotlin, a new programming language (v1.0 released in 2016), as an official language for developing Android applications [2]. Since then, Android developers have been able to develop Android apps using: a) Java, b) Kotlin, or c) both languages.

Kotlin is a programming language that combines object-oriented and functional features, some of them not present in Java or not available for Android development.<sup>1</sup> Kotlin is compiled to Java byte code, which means that a) an application written in Kotlin can be executed on the Java virtual machine (JVM), and b) Kotlin is fully interoperable with Java, i.e., Kotlin code can invoke programs written in Java and vice versa.

The adoption of Kotlin as an official development language for building Android applications has resulted in three

main scenarios. Android developers can: 1) start writing an application from scratch in Kotlin, 2) evolve their Android apps, initially written in Java, by adding Kotlin code and maintaining the existing Java code, 3) totally migrate an application, initially written in Java, to Kotlin. Recently, Coppola *et al.* presented the first characterization of migrations of Android apps from Java to Kotlin [3]. They studied the evolution of such apps by using metrics based on the amount of Kotlin and Java code (LOC) and numbers of files. Their results show that the transition from Java to Kotlin was in general a) fast (rapid transition between languages), and b) unidirectional (the ratio of Kotlin over total code was often increasing during their evolution).

In this paper, we go one step further on regarding the characterization of the migration of Android apps to Kotlin. We conduct a qualitative study to study *why* Android developers have migrated their applications from Java to Kotlin and bring together their experiences about the migration process. This study is important for understanding the limitations of the traditional way of writing Android apps (i.e., using Java language) from the Android developers' perspective. Moreover, we focus on developers who have begun migrating but have not finished at the moment of carrying out this study (i.e., their Android apps contain both Java and Kotlin code).

To perform the study, we first executed code analysis to identify commits on open-source Android applications that have migrated Java code to Kotlin. From those commits, we found the developers that wrote them, i.e., that migrated code from Java to Kotlin. Second, we contacted those developers via email to ask them why they migrated their Java code to Kotlin and their main reasons for doing so.

In total, we received responses from 98 developers that had migrated code on open-source Android apps published

1. <https://kotlinlang.org/docs/reference/comparison-to-java.html>

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on app stores. This study complements the one carried out by Oliveira *et al.* [4], where seven developers were interviewed to gain knowledge about the adoption of Kotlin in mobile development. We also complemented the interviews with a study of the grey literature to detect problems related to the adoption of Kotlin that were not mentioned by developers.

A focus on migration from Java to Kotlin in Android development is crucial because we believe that, since the official adoption of Kotlin, Android development has entered a new era. We hypothesize that, given the increasing support that Google has given to Kotlin on Android, all Android development could eventually move from Java to Kotlin. For this reason, we consider that it is essential to understand why developers migrate Android apps from Java to Kotlin, in order to a) uncover the difficulties developers have encountered and b) help and support them with documentation, techniques and tools for development and migration activities. In this paper, we identify potential directions that the research community could focus on to help developers overcome such difficulties.

The contributions made by this paper are:

- A detailed list of the main reasons that Android developers give for migrating to Kotlin. This could encourage other Java developers to migrate to Kotlin.
- A list of experiences, takeaways and recommendations from our study, that could be used by both Android developers (e.g., to decide whether to migrate to Kotlin or not) and by researchers (e.g., to propose solutions that overcome the current problems developers face).

The paper continues as follows. Section 3 presents the methodology. Section 4 presents the responses of the research questions. Section 5 discusses the threats to validity. Section 6 presents a discussion and future work. Section 7 presents the related work. Section 8 concludes the paper.

## 2 BACKGROUND AND MOTIVATION

In this paper, we focus on the migration of applications from Java to Kotlin. This type of migration has some particularities, and differs from other types of migrations, e.g., of legacy systems. A legacy system can be defined as “a system that significantly resists modification and evolution” [5]. Bisbal *et al.* [6] mention that legacy systems can cause problems, since they usually run on obsolete hardware and lack clean interfaces to interact with other systems. The migration of Java to Kotlin has some key differences with legacy migration. For example, the underlying run-time environment (i.e., the Java virtual machine, ART and Dalvik machines for Android) does not need to be updated: Kotlin and Java are compiled to Java bytecode. In addition, the communication between migrated and unmigrated components in legacy migrations (e.g., COBOL to web [7]) needs *wrappers* ([6], [7]) or *gateways* ([5], [6]). Conversely, the interoperability between Java and Kotlin means that wrappers and gateways are not necessary for migrating from Java to Kotlin. Consequently, developers can, for instance, introduce Kotlin code into their Java apps without changing either the environment infrastructure or the Java code. According to Oliveira *et al.* [4], developers seem to consider this interoperability one of the great benefits of

adopting Kotlin, even though there are inconveniences and disadvantages to be tackled, such as some problems with language features and development tools.

In any case, since it was declared an official language for Android development in 2017, Kotlin has been increasingly adopted ([3], [8]) and some developers have decided to totally or partially migrate their apps from Java to Kotlin. The transition from Java to Kotlin was recently examined in two previous studies, one by Coppola *et al.* [3], and another by Gois Mateus *et al.* [8]. Both studies report that once Kotlin is introduced into open-source Android applications that had initially been written in Java, most of them evolve by having more Kotlin code and less Java code.

Moreover, Coppola *et al.* [3] report that most projects that featured Kotlin in their latest release showed a rapid transition from Java to Kotlin during their lifespan.

Beyond the recent progress on characterizing the development of Android apps that use Kotlin, we note that there are gaps in our understanding about migrations to Kotlin: to our knowledge, no previous work has focused on capturing the motivations of migrating to Kotlin, or the experiences of developers that have already migrated code from Java to Kotlin in Android applications published in app stores.

This paper aims at filling those gaps. In order to do this, the research questions that guide our study are the following:

RQ 1: Why (for what reasons) have developers migrated their Android applications from Java to Kotlin?

RQ 2: Why do developers not fully migrate their Android applications from Java to Kotlin?

RQ 3: What are the main takeaways from developers about migrating to Kotlin?

## 3 METHODOLOGY

In order to respond to the research questions, we carry out a qualitative study with the main goal of collecting data from software developers about the migration of Java code to Kotlin in the context of Android development.

In this study, we choose to directly ask to the developers their motivations behind deciding to migrate from Java to Kotlin. The most suitable approach for obtaining this information is to employ qualitative data collection and analysis techniques, rather than other techniques such as experiments or quantitative surveys [9].

In Section 3.1 we present the overall research design. Then, in Sections 3.2, 3.3 and 3.4 we describe the methods for responding to each research question.

### 3.1 Overall Research Design

Our research design was articulated as follows.

First, in order to sample the population that was able to participate in our study, we performed code analysis to detect commits that migrated code from Java to Kotlin. Using these commits, we identified the developers who had written them. This step is explained in Section 3.1.1.

Second, we performed a qualitative study, consisting of contacting the previously identified developers with the goal of asking them about the migration process that they had carried out. We contacted all the previously identified developers by email, presenting them with a short semi-structured interview. We defined these interviews as semi-

structured because the interviewees were free to answer the questions without pre-coding the answers, as usually done in a questionnaire [9]. The methods that we applied in executing the study are explained in Section 3.1.2.

Third, we carried out content analysis to highlight the developers' main motivations for opting to migrate from Java to Kotlin. The methods we applied in this analysis are explained in Section 3.1.3.

Fourth, we complemented the qualitative analysis described in Section 3.1.2 with an analysis of the grey literature about Kotlin migration. This analysis aims to detect topics discussed and not discussed by developers during the mentioned interviews. We present the methodology for collecting and analyzing the grey literature in Section 3.1.4.

### 3.1.1 Identifying Developers That Have Migrated Code

**3.1.1.1 Definition of Migration Commits.** In this work, a *migration commit* is a commit that removes a piece of code written in Java and introduces code written in Kotlin. For example, commit 3638be from application `Chicago Commutes` removes a file named `GPSUtil.java`, written in Java and introduces a new one, `GPSUtil.kt`, written in Kotlin. Both files provide the same functionality: a method that returns the position given by a smartphone's GPS.<sup>2</sup>

**3.1.1.2 File-Level Migration Commit.** This paper focuses on one type of migration, which we call *file-level migration*, that corresponds to commits that migrate code by removing one Java file and adding one new Kotlin file with the same name.

The heuristic for detecting such commits checks, for a given commit  $C$ , whether it removes a Java file named  $F.java$  and adds a file named  $F.kt$ .

**3.1.1.3 Collecting Migration Commits Using the MigA Tool.** To identify developers that have written migration commits from open-source repositories, we implement an open-source tool called MigA [10].

MigA is built on top of Coming [11], a framework for studying the evolution of applications. Coming provides functionality to, for instance, extract and analyze the source code changes introduced by each commit from a GIT repository. In particular, MigA aims to detect commits that migrate code from Java to Kotlin.

MigA takes the location of a cloned GIT repository as its input. It navigates each branch from the repository in chronological order, starting from the oldest one.

During the commit navigation, MigA analyzes each commit by calling a pipeline of commit analyzers. Commits belonging to several branches are analyzed only once. For each commit, an analyzer from MigA inspects the source code files that are added, removed and modified by the commit. More specifically, it applies the heuristic described in Section 3.1.1.2: it stores a commit if it removes a Java file and also adds a new Kotlin file with the same name.

Finally, it outputs a list of the migration commits previously filtered. For each commit, MigA reports: a) commit ID (SHA-1), b) developer's user name, c) developer's full name, d) developer's email, e) branch(es) it belongs to, and f) date. That information allows us to contact developers that have migrated code.

The architecture of MigA (inherited from Coming) allows users to add new commit analyzers via its extension mechanism. Using them, researchers could, for instance, encode new heuristics in MigA for detecting migrations that are not covered by this paper.

### 3.1.2 Data Collection

To address our research questions, we conduct a qualitative study [12]. Our study is exploratory [13] and applies short semi-structured interviews, following a *purposive sampling* strategy [14] based on the data retrieved in Section 3.1.1.

First, from each migration commit previously retrieved, we glean the name and username of the developer that made the commit. Emails addresses are collected by querying GitHub API, using the username as input.

Then, we send a personalized email to each developer, that mentions that we have analyzed the code of her/his application (mentioning the app name), and that we have detected that she/he wrote at least one commit that migrates code from Java to Kotlin.<sup>3</sup> We first ask developers a single question via email: "*Why did you migrate code from Java to Kotlin?*". When we receive an answer from that developer, we identify the main points discussed in the answer, using content analysis, and we ask new questions accordingly. In addition to these questions, we ask other questions that we have predefined. Examples of those are: a) "*Which Kotlin features do you like the most?*" b) "*Did you use the auto-converter code tool provided by the IDE?*", c) "*Which was the criterion (if any) to choose to migrate those classes?*". The complete list of questions is available in our appendix [15].

We choose a qualitative study format, composed of an initial question, and followed by a semi-structured interview, following the recommendations given by [13], which indicates that giving the interviewee freedom to answer open-ended questions such as the ones proposed in our semi-structured interviews offers a number of advantages, such as observing the answers and asking further questions according to what is observed.

Moreover, we choose to carry out a qualitative study because, as suggested by [13], it can be used as a pre-study for a more thorough investigation, and may provide new possibilities that could be analyzed. In Section 6.2, we discuss new possibilities raised by our qualitative study.

### 3.1.3 Collection of Results and Summary

To summarize the results from the study, we carried out content analysis [12]. We first carefully read through all the answers received, identifying their main motivations and assigning them a code. This process of coding allows us to summarize the answers from our interviewees inductively in order to discover new perspectives and insights.

Our approach follows two ways of coding derived from grounded theory [16]: Open coding and Axial coding. Here we explain the steps.

**Open Coding.** The open-coding process consists of breaking down the content to be analyzed (e.g., responses to our emails) into different parts, each identified by a *code*. Then,

2. Migration commit: <https://github.com/carlphilipp/chicago-commutes/commit/3638be60c8bd144b968f044c0ded218e19697d69>

3. Even if a developer has performed different migrations, we send only one email.

we label them with words or short phrases, which we denominate *codes*. To carry out this step, we collect all codes discussed in each email thread (i.e., the original emails with answers and responses, if any). For example, from a statement such as: “*I moved on from Java to Kotlin because I liked the features that are present in Kotlin and C++, but not in Java, [...] also because of extension functions*” we extract the codes `Like features from C++`, and `Like new feature extension functions`. More examples are listed in our appendix [15]. At the same time, we also label the emails that contain valuable information for responding to the research questions, e.g., why developers migrated to Kotlin.

*Axial Coding*. Once we have read all the emails and collected all the codes, we merge the codes that are equivalent or related. For example, the codes `Limitation of JVM/JDK and Java development stuck with old Java version` were extracted from two emails. However, they refer to the same issue: migration due to the limitations of Java source code version (Java 6) when targeting all Android devices. These are merged resulting in a new code: `Find Java a limitation from Android development`. Once we obtain the final list of codes, we categorize them. In total, we find 74 codes, which are available in our appendix [15].

*Classification of Emails*. Once we obtain the final list of codes, we look through all the emails again to assign each with a code. To do this, we create a spreadsheet where each column is a code  $C$  and each row corresponds to a developer  $D$  that we have interviewed. Then we read each email  $E$  from developer  $D$ : for each code  $C$ , we mark the cell  $D, C$  if the code is present in any of the emails from developer  $D$ . Otherwise, we leave that cell empty.

### 3.1.4 Analysis of the Grey Literature

We complement the qualitative study with a secondary analysis [9] of the grey literature. The main goal of this analysis is to identify which of the reasons for migration mentioned by developers were also mentioned by the grey literature. In this paper, we focus on tutorials and blog entries.

To collect them, we execute two queries on Google: 1) Android Java Kotlin migration, and 2) Android Java versus Kotlin. Then, we inspect the top-25 sites returned, and apply the methods explained in Section 3.1.3 to extract codes from them. Our appendix includes the links to all sites analyzed in the grey literature.

Please note that the study of the grey literature does not aim to report the codes that are most discussed, but to detect those that the developers mentioned. To respond to our research questions, we carry out a secondary analysis [9] based on an additional source (the grey literature), rather than a triangular study (which involves using two or more methods of data collection [17]).

To complement the study, in the discussion Section 6.1, we present codes from the grey-literature that have not been mentioned by developers.

## 3.2 Method for Responding to RQ 1: Why Have Developers Migrated Their Android Apps to Kotlin?

To respond to RQ 1, we inspect each code  $C_i$  (determined by using the method explained in Section 3.1.3), and decide

whether the code could be a reason for migrating or not. If it is, we read all the emails associated with code  $C_i$  and validate if the developer who wrote each email mentions  $C_i$  as a reason. It should be noted that it might be the case that some codes are related to one another. For example, one code states that developers like the Extension Functions feature, and another code does the same with the Data Classes feature. In those cases, we report a single reason that covers both codes. Finally, we report the 10 most frequent reasons that we find.

## 3.3 Method for Responding to RQ 2: Why not Fully Migrated?

To identify why some developers have not yet finished a migration, we first identify the applications that have been *partially* migrated: ones whose latest versions contain both Kotlin and Java. In order to do so, we analyze the amount of code written in Java and in Kotlin from the first and last commit in each app. If the application has Java code in the initial version but none in the last one, we consider it *fully* migrated. Conversely, if the application has both Java and Kotlin code in the latest one, we consider it *partially* migrated.

Then, we apply the methods explained in Section 3.1.1 to the set of partially migrated apps,<sup>4</sup> to retrieve developers that have migrated code. Finally, we ask them about their reasons for not having finished the migration process, and why they still have Java code in their codebases.

## 3.4 Method for Responding RQ3: Migration Takeaways

To answer RQ 3, we follow the same methods as for responding to RQ 1 (Section 3.2), but include an additional step. When we manually analyze each email, we also capture the codes that are related to the experiences of the developers during the migration. For example, from the statement: “*Auto-converter does its job only half, still need to go through and fix some things*”, we mark that the developer wrote a takeaway related to the code: `Had issues when converting using auto-converter`.

## 3.5 The Data Under Study

In this section, we first present the applications that we analyze to respond to these research questions. Then, we report the amount of migration commits we find in those apps.

### 3.5.1 The Dataset of Android Applications

We define two main construction criteria in our dataset of applications. First, the version history of the applications to study must be tracked on the Git system and publicly available in development platforms such as GitHub. These criteria allow us to apply the heuristic discussed in Section 3.1.1.2. Second, to avoid analyzing “toy” projects that developers might upload to such platforms, the apps must be published on an app market, i.e., official ones such as Google Play or unofficial ones such as F-Droid.

4. At the moment the study was done, the partially migrated apps analyzed still had Java code.

To collect the largest number of open-source Android applications, we focus on two datasets: 1) F-Droid,<sup>5</sup> an app market of open-source apps, and 2) Android Time Machine [18], a dataset of apps published on Github.

In total, we collect 2,167 open-source Android applications that fulfill the criteria mentioned above. Then, we use the heuristics for filtering Kotlin applications presented in [8]. At the moment the study was performed, the partially migrated apps analyzed contained Java code. We find 374 out of 2,167 that have at least one line of code written in Kotlin. Those apps have a median of: a) 331 commits, b) 139 files, and c) 7951 lines of code. More statistics are available in our appendix [15].

To respond to RQ 2 (why apps are not fully migrated), we first detect the applications that have not been fully migrated. We find 214 out of 374 apps initially written in Java that have been partially migrated (i.e., that have both Kotlin and Java code in the latest commit).

### 3.5.2 Finding Migration Commits and Developers

We execute MigA on the 374 apps that have at least one commit with at least one line of code written in Kotlin. We mine commits from all branches, following the suggestion from [19]. In total, we find 3520 migration commits written by 362 different developers. 95.7% of these commits (3368/3520) belong to the active branch (usually named *master* or *development*). The remaining 152 commits belong to other unmerged branches. Finally, from those migration commits, we retrieve the usernames, full names, and emails of the developers. In total, we find 362 distinct developers, who will form the target of our study.

## 4 RESULTS FROM THE QUALITATIVE STUDY

We received responses from 98 developers, ~27% of the total contacted (98/362), with all having developed distinct applications.

Table 1 shows an extract of the summary of the codes obtained using the methods described in Section 3.2. The complete table is presented in our appendix [15]. We now respond to the research questions based on those results.

### 4.1 RQ 1: Why (for What Reasons) Have Developers Migrated Their Android Applications From Java to Kotlin?

We present the 10 most frequent reasons for migrating Java code to Kotlin that we were able to identify from the interviews. We recall that a qualitative study (like ours) is not statistically representative of the whole population under study. Consequently, what we find are the 10 most relevant reasons among the interviewees.

Each reason, *i*, is related to a code labeled as ‘RS: *i*’ in Table 1. In this section, reasons are sorted according to the number of developers that mention each reason. We also group the codes according to different categories: e.g., Support (i.e., from Google and/or JetBrains), Design, and Language features.

#### 4.1.1 Reason: To Avoid Errors by Using Safer Code (RS: 1)

One of the biggest problems in Java is the way it handles *nulls*. Incorrect manipulations of them lead to *java.lang.NullPointerException* (NPE). As reported by Coelho *et al.* [20], *java.lang.NullPointerException* was the most reported root cause (27.71%) found in issues reported in over Android projects. Moreover, they found that 51.96% of those projects reported at least one exception stack trace on which the NPE was the root cause.

Kotlin eliminates the possibility of empty pointers from a compilation perspective: potential NPEs are detected at compile time instead of crashing apps at runtime.

Forty-two developers stated that they decided to migrate to Kotlin to obtain safer code (i.e., *null safety*). For example, one developer wrote: “I researched a bit on the language and the focus on null safety and immutability sold me on trying to avoid some past bugs”. Another says: “One of the reasons that motivated me to migrate to Kotlin is Null Safety: reduces errors and I don’t have to think if an object may become null”.

This reason is related to the *maintainability of applications* and is discussed by articles from the grey literature, e.g., [21], [22].

#### 4.1.2 Reason: To Follow Google (RS: 2)

Thirty-two developers told us that one of the main reasons for migrating to Kotlin was the fact that Google had adopted it as an official Android programming language.<sup>6</sup> This adoption means that Google: a) expands documentation, resources and support for Kotlin development, b) enriches the IDE Android Studio to support Kotlin, c) provides *Android KTX*, a set of Kotlin extensions for the Android platform. One developer told us: “I liked Kotlin but Kotlin was an unofficial language for Android development in Dec 2016. But after one year, Google announced Kotlin was first-class language for Android development. So no more worry about Kotlin being banned and I migrated Java to Kotlin”. Another developer told us: “Kotlin being announced as the primary language by Google, we wanted to keep the product up to date with the latest innovations available in the market”.

Google’s adoption of it boosted the popularity of Kotlin [4]. For example, one developer told us: “I got interested in Kotlin after I saw some Kotlin snippets in the Android API documentation so I looked into it a bit more and I liked some of the codes I saw”.

Eight developers also remarked on the role of JetBrains, the company that created both the Kotlin language and the IDE IntelliJ IDEA. One of them told us: “Another reason that influenced me into deciding to migrate to Kotlin was the support Kotlin has, being backed up by JetBrains and Google [...]. Since Google is pretty much the Android authority, it’s wise to follow the best practices they recommend”.

Also, developers underlined the importance of the IDE Android Studio (which is based on the JetBrains’ IDE IntelliJ IDEA). One told us: “The IDE support, debug information, and bytecode viewer is a killer for senior Android devs to play with”. There is one prominent functionality that it provides: a tool for automatically converting a Java file to Kotlin “with the

5. F-Droid: <https://f-droid.org>

6. Kotlin official language for Android: <https://developer.android.com/kotlin>

TABLE 1  
The Most Frequent Codes Mined From the Survey With Developers

Category	Code	#Dev
Support	Like Google support (RS: 2)	32
	Like JetBrains support (RS)	8
	Highlight Importance of IDE for Kotlin	6
	Adopted due to coolness factor (RS)	4
Advantage of Kotlin code with respect to development and maintainability	Reduce code (RT: 1)	34
	Easier to read/clear/write/syntactic sugar/easier to maintain (RT: 1)	23
	Kotlin has clear syntax	17
	Less Redundant/less verbose	12
	Little-to-no boilerplate code	9
	Kotlin is a modern language/has features from modern languages (RS)	5
	Code more dense/heavy	4
Efficient language	2	
Design	Ease of implementing MVI (Model-View-Intent) architecture (RS:3)	6
	Ease of implementing MVVM (Model-View-ViewModel) architecture (RS)	1
	Availability of Built-in design patterns (e.g., with Extension functions)	1
Relation with other languages	Don't want to use Java anymore (RS: 7)	13
	Find Java a limitation for Android development (RS:8)	10
	Like Scala (RS: 6)	5
	Like Kotlin Features from C++ (RS: 10)	4
	Kotlin has more extensions than Java native package	3
	Don't like Java (RS)	2
	Like Kotlin Features from Haskell (RS)	2
	More similarity with Java w.r.t other JVM languages (RS)	2
	Not a fan of Kotlin	2
	Like Python	1
Similar to Swift (RS)	1	
Language Features	Like Null safety/Nullability support (RS:1)	42
	Like Extension functions (RS: 3)	23
	Like Coroutine (RS:3, RT: 2)	21
	Like Data class (POJO) (RS: 3)	16
	Highlight Interoperability with Java (RS: 5)	15
	Like lambdas (RS: 6)	14
	Like Functional programming available in Kotlin (RS: 6)	11
	Use Coroutines instead of ReactiveX (RS)	8
	More features than Java (RS)	7
	Like Function as parameters/Higher-Order functions	6
	Like Immutability	5
	Highlight Kotlin standard/built-in library	5
	Like no getters/setters	4
	Like streams	4
	Like built-in API for manipulating collections	4
Like default parameters	4	
Find Kotlin safer than Java	3	
Productivity with Kotlin	Increase productivity	5
	Faster development	4
	Faster delivery	3
Running platforms	Like Kotlin to write server side apps* (RS)	7
	Interested in multiplatform with Kotlin (RS:9)	6
	Kotlin Android Extensions plugin (Android KTX) (RS)	2
Auto-converter	Use the auto-converter alongside the migration process	36
	Had issues when converting using the auto-converter (RT: 2)	24
	Use the auto-converter first, then manual conversion	2
Migration process	App migrated to learn Kotlin (RS: 4)	19
	Migrating using "Boy scout rule" (RNM: 1)	14
	Only new features would be implemented in Kotlin (RNM: 2)	10
	Migrated in one step (i.e., one single commit)	9
	Migrated only by hand (only manual coding)	6
	No time to finish (RNM: 3)	5
	Only new files in Kotlin/Old code kept in Java (RNM)	3
Started migration with data class (POJO)	2	
Performance	Affirm no overhead in performance	2
	Affirm no overhead APK size	1

\*We don't discuss this code in this paper as we focus on Android development.

Annotations RS, RNM, and RT refer to codes used for responding to research questions 1, 2 and 3, respectively. Those numbered are detailed in Section 4. The full table is available in our appendix [15].

click of a button". One developer told us: "Thanks to JetBrains, I migrated it in several hours, and it worked on the first launch, which was very promising".

This reason is related to the *Android development support* and discussed by articles in the grey literature such as [23], [24], [25].

#### 4.1.3 Reason: Waiting to Use a Modern Programming Language (RS: 3)

Most developers who answered our questions found Kotlin to be a *modern* programming language that provides several built-in features that are not available natively in Java. Some of them are: a) Extension functions (23 developers highlighted this), b) Coroutines (21) c) Data classes (16), d) others features (Smart casts, Type inference, Control flow). For instance, the *Extension function* feature provides the ability to extend a class with new functionality without inheriting from the class.<sup>7</sup> One developer wrote this about it: "apart from providing a clean way to refactor the code, extensions allow an alternative to Abstraction/Inheritance in order to achieve the Open/Closed Principle, which is invaluable".

Six developers remarked on the *built-in design patterns* provided by Kotlin, which enforce some of the best practices of Java by design. For example, the *Singleton* pattern using the keyword 'Object' and the *Decorator* pattern using the keyword 'by'.

This reason is related to the *development* of applications. The grey literature we inspected also highlighted those features, for example, extension functions were mentioned by [23], [24], [26], [27], [28], and coroutines by [23], [28], [29].

#### 4.1.4 Reason: For Learning Purposes (RS: 4)

Sixteen developers mentioned to us that they started developing their apps with for learning purposes: they generally try and test new technologies such as Kotlin while they develop an app. (Note that, beyond that this purpose, as our inclusion criteria indicate (Section 3.5.1), all analyzed apps were published on apps stores such as Google Play).

Those developers migrated Java code to Kotlin while they were learning to program in Kotlin. One of them told us: "I migrated my mobile application from Java to Kotlin mainly for learning purposes. Even though this project is in production, it is a great playground to stick with the last Android technologies and experiment new tools".

This reason is related to developers' *training education and skills* and is discussed by articles in the grey literature, e.g., by [26].

#### 4.1.5 Reason: To Use a New Language That is 100% Interoperable With Java (RS: 5)

Fifteen developers mentioned the advantage of full interoperability between Kotlin and Java. This interoperability allows developers to *mix* Java and Kotlin code. Thus, the migration can be performed gradually, i.e., a commit migrates some classes which can interact with unmigrated classes. As one developer said: "We could implement new functionality in Kotlin while leaving the existing Java classes intact. Otherwise, the port to

Kotlin would have been infeasible". This is aligned with the finding from Oliveira *et al.* [4]: their interviews with seven developers present interoperability as a great benefit of adopting Kotlin. Interoperability is a key factor for conducting low-risk migrations by *gradually* migrating the code. For instance, the Android app of Duolingo,<sup>8</sup> a language education platform, was fully migrated from Java to Kotlin in two years [30]. This was possible due to the interoperability of the languages: during that period, Duolingo apps contained both Kotlin and Java code. As Duolingo's developers report, this gradual migration allowed them to apply strict testing, code review and code style of each part of the migrated application.

This reason is related to the *development and maintainability* of Android applications. The grey literature also highlights interoperability as one of the most important features, e.g., [22], [23], [27]. Moreover, Sommerhoff [26] states that, thanks to interoperability, the migration of large projects can be performed gradually.

#### 4.1.6 Reason: To Use a Functional Programming Language for Android Development (RS: 6)

Eleven developers migrated to Kotlin because it is a *functional-oriented* programming language, and it provides several *functional* features that are not available for Android development using Java 6 (e.g., lambda is available in Java 8 +). The *Higher-Order functions* feature (i.e., the possibility of passing a function as an argument) was highlighted by fourteen developers. Five developers told us they were mainly Scala developers. Kotlin gives those developers the possibility to write Android applications using a functional paradigm, just as they do with Scala.

This reason is related to the *development and maintainability* of applications. Several articles from the grey literature highlight functional features as one of the main advantages of adopting Kotlin, e.g., [23], [24], [26].

#### 4.1.7 Reason: To Avoid Java Language (RS: 7)

Some developers migrated their tools because, as they confessed, they do not like the Java language. Thirteen developers mention that, thanks to the possibility of coding Android apps with Kotlin, they no longer use Java. For example, one wrote: "I don't and haven't ever really liked Java. I only wrote it in Java because that's what Android dictated. When Kotlin came around, it looked like a nicer language, and was fully compatible".

Since Google officially adopted Kotlin, developers who do not like or do not use Java can now develop Android apps in another programming language. One of them wrote: "I migrated from Java to Kotlin because I don't really know how to work with Java. The app was written in Java because there was no officially supported alternatives for Android development".

This reason is related to the *development* of applications.

#### 4.1.8 Reason: To Avoid Android Platform Fragmentation and the Limitation of Java Versions Used for Android Development (RS: 8)

One of the main obstacles that Android developers face is the fragmentation of the Android platform. To target all

7. Kotlin Extensions: <https://kotlinlang.org/docs/reference/extensions.html>

8. Duolingo: <https://www.duolingo.com/>



platforms, Android developers who use Java are obliged to use Java 6, which does not include coding features such as *lambdas and extension functions*. We call them *modern features* as they are typically available on modern programming languages such as Scala, Golang, Rust, Swift, etc. To use Java 8 and its modern code features (including collection API, streams and lambdas), their apps must target one of the latest Android OS versions (API level 24+).<sup>9</sup> This implies that Android devices with older OS versions cannot run applications written using Java 8.

Ten developers noted their annoyance about programming on Android using Java 6. One of them said: *“I was sick of using Java. As a professional Android developer there is no reason to use Java, especially the incredibly limited version of Java you get on Android.”*

The majority of the developers that answered us stated that migrating to Kotlin was a way to “hack” this problem: Kotlin has standard libraries that provide features available on Java 8+ (such as lambdas and streams). Gois and Martinez [31] describe these Kotlin code features that are not available in Java for Android development. Moreover, Kotlin has as advantage that its source code is compiled to Java 6 bytecode. Thus, apps written in Kotlin can be executed on any Android device. This simplifies the development task. For example, one developer wrote: *“I forked a library into my project and it was Java 8 only because it used streams, but with Kotlin I got that working in Java 6/7 which is how most android works”*.

This reason is related to the *development and deployment* of Android applications and is also discussed in the grey literature, for example, by [23], [32].

#### 4.1.9 Reason: To Achieve Multi-Platform Development (RS: 9)

It is worth mentioning that, even though no developers mentioned it as their main reason for migrating, seven of them pointed out that the migration to Kotlin could allow them to achieve multi-(cross-) platform development.<sup>10</sup> Currently, mobile developers can write the business logic of a mobile application using Kotlin and share it in their Android and iOS projects, allowing them to reduce development time and effort by reusing business code.<sup>11</sup>

This reason is related to the *portability* of Android applications.

#### 4.1.10 Reason: To Use Features Provided by Other Programming Languages (RS: 10)

Some developers told us that they master or prefer other non-Java Virtual Machine (JVM) programming languages such as C, C++, Python or Haskell. As Android developers have been “forced” to program in Java, the introduction of Kotlin for Android development has been an opportunity for those developers to use some features also available in their favorite programming languages. *Named and default*

9. Java 8 support: <https://developer.android.com/studio/write/java8-support>

10. Kotlin multiplatform: <https://kotlinlang.org/docs/reference/multiplatform.html>

11. Mobile cross-platform: <https://www.jetbrains.com/idea/mobilecrossplatform/>

*parameters* in Python and *Operator overload* in C++ are features present in Kotlin that developers mentioned in their answers.

This reason is related to the *development and maintainability* of applications. The grey literature also highlights these features of Kotlin, e.g., named and default parameters [24], [26], [33], and operator overload [29], [32].

## 4.2 RQ 2: Why do Developers not Fully Migrate Their Android Applications From Java to Kotlin?

Thanks to the interoperability between Kotlin and Java, developers do not need to migrate their applications completely. We asked developers of not fully migrated apps why they had not yet finished the migration. We set out the most important reasons identified. Each is related to a code labeled as ‘RNM: *i*’ from Table 1.

### 4.2.1 The “Boy Scout” Rule (RNM: 1)

Fourteen developers migrated Java code to Kotlin by following the *“Boy Scout Rule”*.<sup>12</sup> This rule states that the code is migrated if: a) it is necessary to change a Java file, and b) migrating it to Kotlin is simple (i.e., it takes little time).

Unlike from those developers that completely migrated their code, some developers of partially migrated apps only migrated code when there was a particular reason for doing so. For instance, some of these developers told us that they migrated while they were refactoring code. As one wrote: *“Occasionally parts of the application that need refactoring are identified. When refactored, they are migrated to Kotlin”*. Another refactored while converting: *“I converted whenever I had to touch the file for one reason or another anyway, usually combined with a refactoring”*. This way of migrating causes the amount and the proportion of Kotlin code to grow along as the apps evolve.

However, some developers remarked that they do not always follow that rule. For instance, one told us: *“Old classes were migrated to Kotlin when they had changes. Some classes are still in Java because they implement hard logic”*.

The grey literature also mentions the style of migration that follows the “Boy Scout” rule. For instance, Abdelaziz [34] suggests: *“when a Java class raises a bug and needs to be changed, [...] then you can also convert it on the spot.”*

### 4.2.2 New Functionality is Written in Kotlin, Old Functionality Remains in Java (RNM: 2)

Some developers told us that they decided to write only new functionality in Kotlin without migrating the *old* Java code. In other words, components written in Java evolved without any migration, unlike the “Boy Scout” rule. One told us: *“I don’t think I have yet changed any code just for the sake of rewriting”*. Upon encountering a bug in a Java file, these developers keep the Java code. One mentioned: *“I decided that every new feature would be implemented in Kotlin. I would add Java code only to fix legacy code”*. Another developer suggested: *“not touching the old code unnecessarily. Adhere to the principle of ‘work, do not touch’. And only when expanding the functionality of the old Java code, translate it into Kotlin”*.

12. The name ‘Boy Scout Rule’ was coined by a developer during the interview.

Similarly, one told us: “If it was working in Java, it’d continue to work”.

This strategy was also discussed in the grey literature. For example, a post from a development company [35] recommends, according to their experience, “not to convert Java to Kotlin when your existing Java code base is large and in maintenance mode [...] you are not going to save much by putting old code in a new form”. Moreover, this strategy was also observed from a survey by Khadka *et al.* on legacy system modernization [36]. There, some practitioners and respondents to our interviews indicated that “if the legacy systems are working well, then legacy system modernization projects are unlikely to be initiated”.

#### 4.2.3 Time Factor (RNM: 3)

Some developers told us that their applications have still not been migrated because they simply have not had time to finish the migration. This aligns with the finding from the survey by Khadka *et al.* on legacy system modernization [36]. They reveal that, according to the practitioners they interviewed, “finishing any legacy system modernization on time is the biggest challenge”. Others told us they are not in a hurry to complete the migration. Finally, some developers are waiting for the release of particular features from the Kotlin/Android platform. For example, one developer told us: “I am not in a hurry to get to ‘100% Kotlin’, at least not until the future of ‘Kotlin Native’ (for a possible iOS port) is clear”.

### 4.3 RQ 3: What are the Main Takeaways From Developers About Migrating to Kotlin?

We list three takeaways reported by developers about their experience *after* migrating to Kotlin. They are related to codes labelled as ‘RT: i’ in Table 1.

#### 4.3.1 Adoption of Kotlin Produced Less, and Clearer, Code (RT 1)

Thirty-four developers remarked that Kotlin allowed them to write less code than in Java. Seventeen mentioned that Kotlin has better and more precise syntax than Java, producing less verbose and less redundant code. As one told us: “Kotlin is a very concise and expressive language” and “Kotlin strikes a good balance between being concise versus cryptic”. Articles from the grey literature also remark on the reduction in lines of code when they compare an application written in Java with its equivalent written in Kotlin. However, the reduction of lines of source code written differs across the articles. For instance, Trehan [37] and Wilson [38] both report a reduction of around 7%, Caneco [22] reports a 23% reduction, and the reduction observed in the experiment from Uber [39] is 40%. This divergence is a call to do more extensive research on the measurement of code reduction due to adopting Kotlin.

Nine developers remarked that Kotlin allows *boilerplate code* to be reduced, i.e., code that has to be included in many places with little or no alteration. One of the features which aids that reduction is *Data classes*: a model class can be declared in one line. Sixteen developers included *Data classes* in their favorite Kotlin features.

Furthermore, twenty-three developers remarked that Kotlin code is easier to read, write and maintain than Java

code. Twelve developers mentioned that Kotlin has a simpler and clearer syntax than Java. (We recall that *all* developers we contacted wrote their applications using Java *before* migrating -totally or partially- to Kotlin).

Nevertheless, among the 98 developers who replied to us, two developers mentioned that, when they started programming in Kotlin, its compact syntax affected code readability. One told us: “Initially, it felt awkward, but after a month of practice with the language, it was already obvious that the syntax was much improved over Java”. These findings align with those of Oliveira *et al.* [4], which found that the overuse of lambdas and closures can decrease code readability.

*Implication.* The developers agreed that Kotlin allowed them write more concise, less redundant and more precise code. Kotlin helps developers to write and maintain their Android applications. However, Kotlin’s concise syntax might cause difficulties for novice developers.

#### 4.3.2 Careful Use of Auto-Converter Provided by the IDE (RT: 2)

In total, thirty-six developers told us that they had used the code converter provided by the IDE, which converts a single Java file to Kotlin. Some of them indicated that they had started using it while they were learning to code in Kotlin, but then, after gaining confidence, they continued the migration without using the converter. All developers who used the conversion tool told us that they modified the code after conversion. They agreed that the converter helped them to execute the migration and, in general, that the changes that needed made to the converted code were simple. Unanimously, the main reasons mentioned for making such changes after the conversion are: 1) to transform nullable variables into non-nullable, and 2) to make the converted code more idiomatic.

Related to the nullability of variables, developers mentioned that they had to modify the converted code to better support nullability. For example, one told us: “It was also marking variables and properties as nullable too often, I was able to make them non-nullable after the conversion”. We recall that Kotlin, by default, does not allow a variable to hold a null, and null check is done at compilation time. The developer, however, can declare nullable variables by using the operator ‘?’ e.g., `val number: Int? = null`. Then, using the variable, a developer has two main options: 1) to use the safe operator ‘?’ i.e., `number?.toString()`: the method `toString()` is not invoked if the variable is null; 2) to use the unsafe operator ‘!!’ `number!!.toString()`: the method is always invoked, and if `number` is null, it throws an exception. Thus, developers should do something that is typically done in Java: add a guard (an *if* statement) which checks for a null reference before accessing that variable. The auto-converter from the IDE outputs the unsafe operator ‘!!’ in every variable access of potentially nullable variables. Consequently, to make that transformed code more Kotlin-idiomatic (i.e., Null safety, one of the main features of Kotlin), developers would need to remove those ‘!!’ operators. Articles from the grey literature, e.g., [40], [41] present different strategies to remove such ‘!!’ operators.

*Implication.* The auto-converter tool provided by the IDE allows Android developers to obtain an *initial* version of

their applications in Kotlin. However, it is necessary to know Kotlin well in order to modify the code generated to make it more idiomatic.

#### 4.3.3 Simplification of Asynchronous Tasks Using Coroutines (RT: 3)

Asynchronous or non-blocking programming is essential on Android because it allows better user experience and improves application performance. It is used to perform network calls, execute background jobs and tasks, access the local database, and run computationally intensive calculations. There are several manners of implementing asynchronous tasks in Android development with Java: AsyncTasks, plain old threads, Android’s main looper, Android loaders, etc. To simplify the development of asynchronous tasks, some Android developers use external libraries (i.e., non-native concurrency API) such as RxJava.<sup>13</sup> (The survey carried out by Verdecchia *et al.* [42] shows that RxJava was the Java library that was most mentioned by the Android practitioners they interviewed).

Kotlin, conversely, provides coroutines: a built-in mechanism, at the language level, for executing asynchronous tasks. Twenty-one developers highlighted coroutines as one of the best features that Kotlin provides. As one developer told us: *“In my opinion, coroutines allow developers to write easy to read and concise code, that can be read top-down, like a book. I believe that’s a big advantage”*. Another developer remarked: *“coroutines were the cleanest way to implement my complex workflows”*.

Eight developers mentioned that they had replaced RxJava with coroutines. One told us that: *“the code with RxJava looks ‘hacky’ and it quickly becomes a mess”*, and another developer: *“Coroutines are also absolutely great. They have allowed me to drop RxJava, which although very useful, was annoying to work with in complicated situations. Being able to write asynchronous code in direct style is wonderful”*.

As well as all the positive perceptions collected, just one developer told us that, although he uses coroutines, he finds they entail a *“lot of complexity”*.

*Implication.* Android developers can simplify the code for their asynchronous tasks by using the language-level supported feature called ‘coroutines’. Beyond that, further research may need to compare coroutines with other concurrency mechanisms (e.g., RxJava) in terms of other dimensions such as performance.

## 5 THREATS TO VALIDITY

*The Applications Studied Might not be Representative of Open-Source Applications.* We studied 374 open-source Kotlin Android applications coming from two datasets. There is a risk that these apps might not be representative of open-source Android applications written in Kotlin. However, we apply a methodology to capture and analyze the largest number of open-source Android applications published on apps markets.

*Open-Source Apps Might not be Representative of All Android Apps.* Our study focuses on publicly available open-source

apps because we need a repository with visible source code to detect migrations. Thus, we cannot analyze non-open-source apps published on app stores. For further analysis, the list of open-source apps analyzed is available in our appendix [15].

*Heuristic for Detecting Migrations.* We identify developers that migrate code by using one particular heuristic (See Section 3.1.1.2). There could be other manners of migrating code that our heuristic cannot detect. Therefore, more research is required on code migrations, e.g., to define a taxonomy of code migrations.

*Accuracy of MigA.* There might be a risk that a bug in our tool affects the results we present. We manually inspected a sample of migration commits detected by the tool and did not find any anomalies. Our tool is publicly available [10]. Thus researchers can inspect its code, use and extend it.

*Sample.* Qualitative studies such as ours are performed by using a representative sample of the population under study [13]. The *target* population corresponds to developers that have migrated code from Java to Kotlin in Android apps. We create a *sampling frame* by retrieving developers (detected in open-source code repositories) that have migrated Java code to Kotlin. Then, we send emails to *all* of them. It might be the case that the developers that we contact and that reply to us represent neither the Android community nor the Kotlin community. To minimize this risk, we analyze *all* applications from two of the largest Android open-source app repositories: F-Droid and AndroidTimeMachine [18].

*Bias in Responses.* There is a risk that the responses given by the developers are biased: our study captures the experience of developers that successfully migrated and integrated Kotlin code into their codebases. Our methodological approach for finding developers is based on commit analysis. Therefore, we cannot identify developers who tried Kotlin, but later decided not to adopt it (and thus never committed any Kotlin code into their repositories). This would require contacting all developers that had never committed Kotlin code, something which is unfeasible.

*Research Design.* We based our research design on an initial question to reduce the costs to participants. There is a risk that the responses we received did not completely capture participants’ experiences with Kotlin (e.g., a developer forgot to mention one of her/his favorites Kotlin features). To mitigate a developer omitting information, we tried to contact as large a number as possible of developers that migrated code on open-source Android apps.

*Reliability of Answers.* Some answers might not reliably reflect the experiences of the developers that wrote them. As we have a considerable number of answers from developers, having a few imprecise or incorrect answers does not invalidate the overall results.

*Verification of Qualitative Research.* Our study follows a qualitative research method that attempts to interpret a phenomenon (i.e., migrations) based on explanations that people (i.e., developers) bring forward [13]. We follow a verification mechanism used during qualitative research to ensure the reliability and validity of our study. For instance, the open and axial coding (see Section 3.1.3) applied to mine codes from the qualitative data (the emails) was performed by one of the authors of this paper and later verified and validated by the other author.

13. RxJava: <https://github.com/ReactiveX/RxJava>

*Mining the Grey-Literature.* In this paper, we analyze some articles from the grey literature on Kotlin adoption and migration. Our study neither aims to nor claim to be a systematic literature review on those topics. Consequently, there may be, for instance, migration problems that this research does not report, but that have been reported by articles from the grey literature (or other artifacts such as Audio-Video media [43]) that we did not inspect. Nevertheless, in order to be transparent about the process, in our appendix [15] we report the query we use and the links to analyzed sites.

## 6 DISCUSSION AND FUTURE WORK

### 6.1 Additional Codes From the Grey Literature

We list some codes we mine from the grey literature that are not discussed by developers in our primary study. These points could represent future research opportunities, in addition to those detailed in Section 6.2 that arose from the interviews.

*Kotlin is Slower to Compile.* Several posts have tested the compilation time of Kotlin code ([23], [25], [29], [32], [44]). For example, Daga [23] reports a difference of 13% on the compilation time w.r.t. Java. Wilson [38] reports that, after migrating a library named OkHttp’s from Java to Kotlin, the compilation time went from 2.4 to 10.2 seconds. Engineers from Uber [39] found that the Kotlin’s new type inference system adds an overhead of 8% in total compilation time.

*Kotlin Increases the Size of the APK.* Some of the grey literature posts mention the increase in the size of the APKs (the package file format used by Android, which contains compiled code) when Kotlin is used. For example, Wilson [38] reports that, after migrating its library named OkHttp’s from Java to Kotlin, the binary (APK) size increased by 60%. Daga [23] reports an average increases of 800 KB and 1 MB, and Kust [32] reports an approximate 300 KB increase.

*Absence of Checked Exceptions in Kotlin.* Unlike Java, Kotlin does not have *checked* exceptions (i.e., types of exceptions that must either be caught or declared in the method in which it is thrown). Articles from the grey literature highlight some benefits of getting by without them: Daga [23] states “Kotlin does away with them to aid code conciseness”, and Gour [33] states “it can minimize the verbosity and improve type safety”.

*Problems With Wildcard-Types.* Kotlin has neither primitive (raw) types nor Wildcard-types (i.e., the symbol ‘?’ in Java which represents an unknown type in generic programming) [29]. Kotlin code that uses wildcards and that was generated by the auto-converter tool can produce runtime failures according to [34]. This means developers must revise and modify, as we mention in Section 4.3.2, the output from the auto-converter tool.

*Problems With Annotations.* A post by Thornsby [28] mentions that one of the differences between developing in Java and Kotlin is the use of KATP, the official tool for processing annotations. A post by Hofmann [45] states that a problem of adopting Kotlin was related to KATP, which produced build errors when it was integrated into other libraries such as Dagger,<sup>14</sup> a dependency injection library. That integration

was also reported as problematic by [46]. Related to this, engineers from Uber found that using KATP adds a ~95% overhead [39].

*Performance Issues.* Athaydes [47] and BeyksZ [48] discuss and measure the runtime overhead introduced by Kotlin features. The former shows that 8 out of 11 evaluated features have an overhead lower than 5%, with the remaining 3 (Varargs + Spread Operator, Delegate Properties and Ranges) having an overhead that is higher than 10%. We consider that more research on the performance of Kotlin is needed.

### 6.2 Research Challenges

Wohlin *et al.* [13] indicate that an exploratory study, like the one conducted in this paper, can be used as pre-study for a more thorough investigation, and may provide new possibilities that could be analyzed and should therefore be followed up in a more focused or thorough survey. In this section, we present some new possibilities that could be exploited by the research community.

*Auto-Converter Tools.* The study we conduct shows that developers used the auto-converter code and modified the output code to make it more idiomatic. The automated-generated code is like “code written with Kotlin syntax but still keeping Java style”. Future research could define new automated code conversion approaches and tools (like the initial work from [49]) for generating idiomatic code, and consequently, attempting to reduce the modifications that developers have to make.

*Refactoring Kotlin Code After Migration.* A challenge for researchers is to define approaches and tools that propose *refactorings* on Kotlin applications after the migration has been (partially or fully) carried out. We envision two directions. First, for identifying and potentially automatically removing code with technical-debt items, such as code smells and code patterns [50], related to Kotlin code. Existing tools target Java code (e.g., JDeodorant [51]) but, to our knowledge, none targets Kotlin code. Second, we envision refactorings that make Kotlin code (both that written by humans or generated by a tool) more idiomatic. For example, one could propose using new Kotlin features (e.g., *smart casts*) that had not previously been used by the developer.

*Supporting Migration Activity.* A potential research direction is to define guidelines, approaches, and tools that help developers migrate their apps. Gradual migrations are convenient for migrating large applications (e.g., Duolingo [52]) because they allow developers and companies to migrate some parts of their apps while simultaneously being able to evolve other parts, add new features and release new versions.

Gradual (or iterative) migration has already been studied on legacy applications (e.g., [53]). It consists of first decomposing the legacy apps [5] and then integrating the decomposed parts by using *wrappers* (e.g., [54]). Migration from Java to Kotlin does not need such wrappers, as both languages are interoperable. In this scenario, a developer needs to define a *migration strategy* that defines consecutive migration steps, and for each of them, a subset of components or code files to be migrated. This could be challenging, especially on large applications: the wrong selection of files to be migrated could increase the migration effort due to emerging errors [34]. We

14. Dagger: <https://dagger.dev/> envision the definition of guidelines, approaches, and tools

that help developers define a migration strategy and select the correct files, packages, or components to be migrated in one particular step to minimize the migration effort. An initial experiment on file recommendation for migration was performed by [55].

*Estimating the Cost of Migration.* One of the main problems about migrations reported by our study and literature on migration (e.g., [36]) is unfinished migrations due to the lack of time or resources. Models for estimating the cost and effort of migration could help developers and companies forecast these issues. A challenge for researchers that focus on migration is to define models that estimate the cost of migrating Android apps to Kotlin based on existing estimation models [56].

*Kotlin Code Comprehensibility.* In our study, some developers mentioned that the compact syntax of Kotlin affected the readability of the code. A research direction could focus on empirically studying the comprehensibility of Kotlin code. To our knowledge, there is no previous work on this. Future work could focus on defining tools that would attempt to automatically measure code comprehensibility, and to point out sections of code that are difficult to comprehend and should therefore be refactored [57].

### 6.3 Research Ethics

Since our study involved human subjects, as recommended by [13], we considered ethical aspects when we designed the study: 1) we informed subjects of the research project's title and goals, 2) we mentioned our affiliations, and provided links to our professional websites, 3) we explained that participation would help us write a research paper, 4) we guaranteed the confidentiality of the information obtained, i.e., we did not share the answers, 5) every quote included in this research is anonymized, and 6) names of developers have been codified in order to protect their privacy.

Nevertheless, we consider that developers that responded to this study (as well other developers we did not contact) will benefit from this research in the long run because, for instance, we enumerate and detail the various different problems that they encountered during the migration process, allowing the research community to focus on providing solutions to them.

## 7 RELATED WORK

### 7.1 Adoption of Kotlin

Oliveira *et al.* [4] conducted a study to understand how developers deal with the adoption of Kotlin as an official language for Android development, their perception of the advantages and disadvantages of it, and the most common problems they face. Our work has a narrower goal than their study: to study the migration of Android applications from Java to Kotlin. Moreover, the surveys conducted have two main differences: 1) the goal: to obtain the experience of Kotlin adoption [4] versus experience of migration (us), 2) the size: 7 interviewees [4] versus 98 developers that migrated code (us).

### 7.2 Surveys on Legacy System Migration and Software Modernization

Torchiano *et al.* [58] conducted a survey that identified the state-of-the-practice of 59 software migration projects in

Italian industries. There are three main differences to our work. The study differs from our work in three main ways. First, the scope: [58] focuses on industrial applications, and we focus on open-source apps. Second, [58] does not focus on a particular technology, and we focus on Kotlin and Android. Third, the contacted subjects: [58] targets different profiles (39.7% were software developers); we focus exclusively on developers.

Khadka *et al.* [36] conducted an exploratory study to discover new perspectives, insights, drivers of modernization and challenges with respect to legacy systems in industry. It consisted of semi-structured interviews with 26 industrial practitioners. The findings were then validated through a separate structured survey that involved 198 professionals. The differences: our study focuses on open-source apps ([36] focuses on industrial projects) migrated from Java to Kotlin on Android ([36] does not focus on particular technologies).

Other works have focused on the migration of specific technologies by conducting surveys. For example, Razavian and Lago [59] conducted a survey in seven companies to understand the migration approaches from legacy systems to service-oriented applications (SOA).

### 7.3 Empirical Studies on Kotlin Code

Gois Mateus and Martinez [8] found that 11% of the studied open-source applications from Android have Kotlin code. They also found that the adoption of Kotlin increases the quality of applications, expressed in terms of the presence of code smells. Flauzino *et al.* [60] studied 100 repositories of programs containing Java or Kotlin code. They found that, on average, Kotlin programs have fewer code smells than Java programs. Gois and Martinez [31] have studied the adoption of features introduced by Kotlin. Ardito *et al.* [61] conducted a study with undergraduate students to assess the assumed advantages of Kotlin over Java in the context of Android development and maintenance. They found evidence that the adoption of Kotlin led to more compact code. These findings from students are aligned to our findings derived from developers.

### 7.4 Studies on Library Migration

Other works focus on empirical studies of migrating of libraries (e.g., [62], [63], [64]) and recommendations on library migrations (e.g., [65], [66]). For instance, Salza *et al.* [67] focus on studying the migration of third-party libraries in mobile apps. They find that mobile developers rarely update their apps. In this paper, we exclusively focus on the migration of source code.

## 8 CONCLUSION

In this work, we conducted a qualitative study that gathered data from 98 Android developers who migrated code from Java to Kotlin to ask them Why they had migrated that code. Developers found using Kotlin a way to a) use modern features not available in Java in their Android applications (e.g., extending function) and to b) have safer, shorter and less verbose code.

In addition, we defined different research directions extracted from our study based on the difficulties developers had encountered when they migrated code. In future

work, to help developers to overcome the difficulties they currently have when they adopt Kotlin and migrate code from Java to Kotlin, we plan to work on: 1) defining an approach that translates code from Java to Kotlin and produces more idiomatic code; 2) defining an approach that refactors Kotlin code to remove code smells, to improve code comprehensibility, and to obtain more idiomatic code; 3) helping developers to migrate large applications by presenting migration strategies (for example, suggesting files and components to migrate first); and 4) improving the testing of the migrated parts of systems under migration, as well as the unmigrated parts that interact with the migrated parts.

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