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HYBRID METHODS FOR REDUCING DATABASE SCHEMA TEST SUITES:EXPERIMENTAL INSIGHTS FROM COMPUTATIONAL AND HUMAN STUDIES

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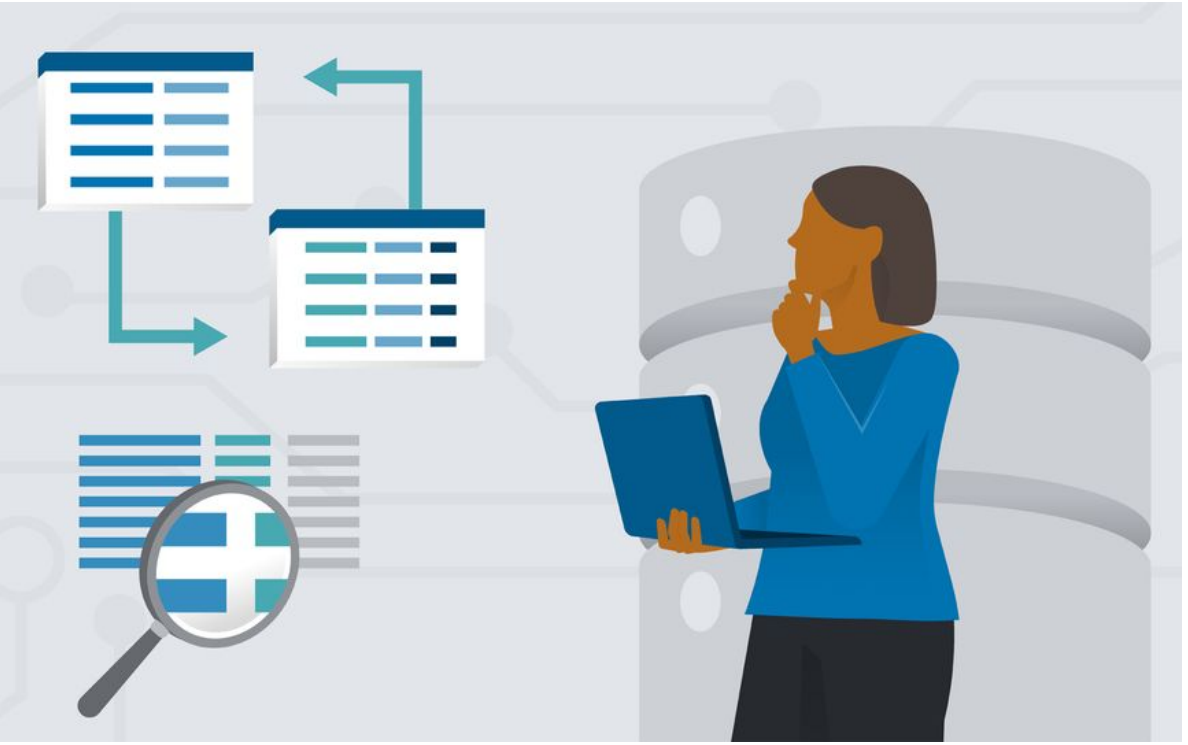
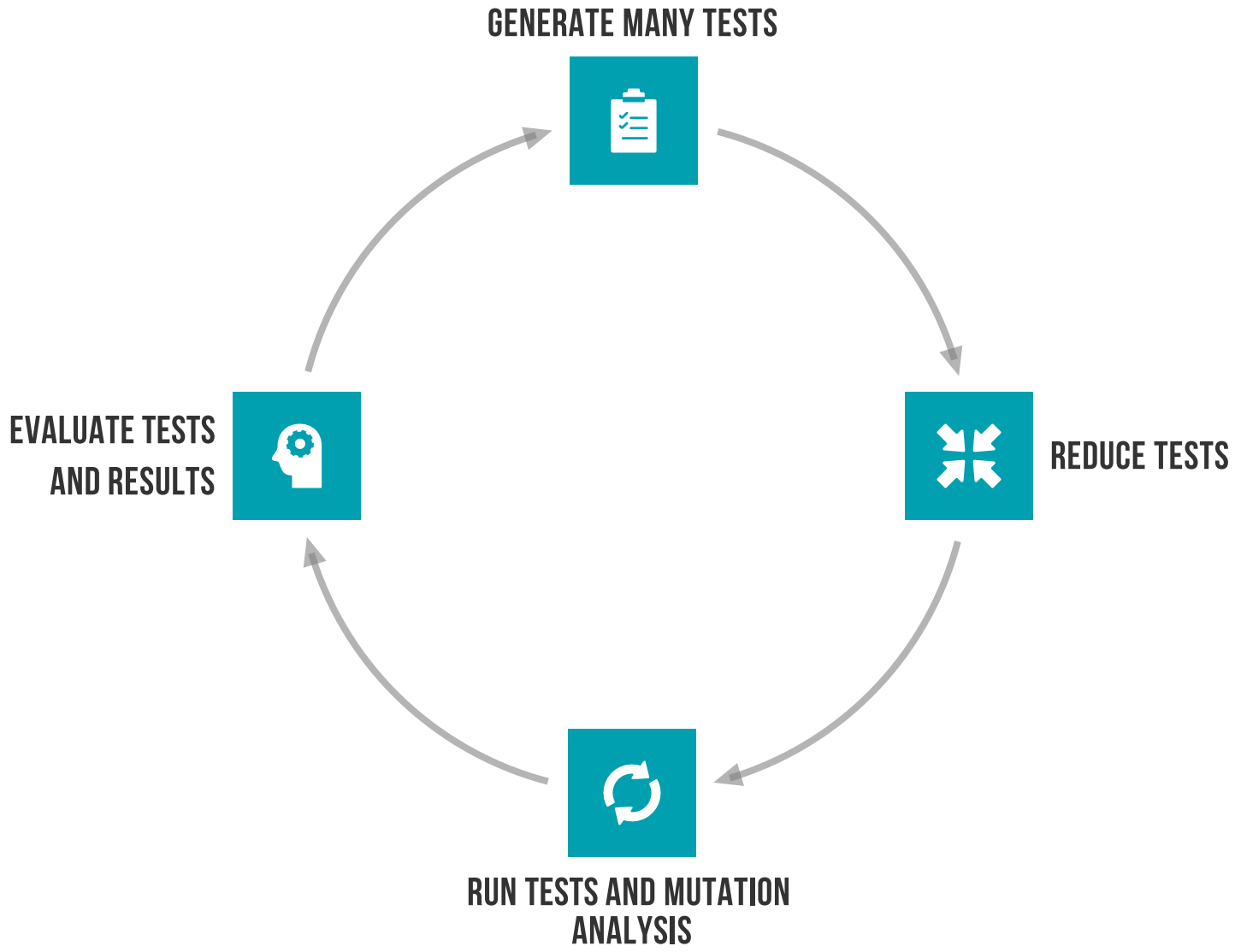
“A good [relational] database schema should have many constraints. You should test them too.”

Szymon Guz, 2011



```sql
CREATE TABLE person (
    id int not null,
    last_name varchar(45) not null,
    first_name varchar(45) not null,
    gender varchar(6) not null,
    date_of_birth date not null,
    PRIMARY KEY  (id),
    CHECK (gender IN ('Male', 'Female', 'Other'))
);
```

AUTOMATICALLY GENERATING TESTS



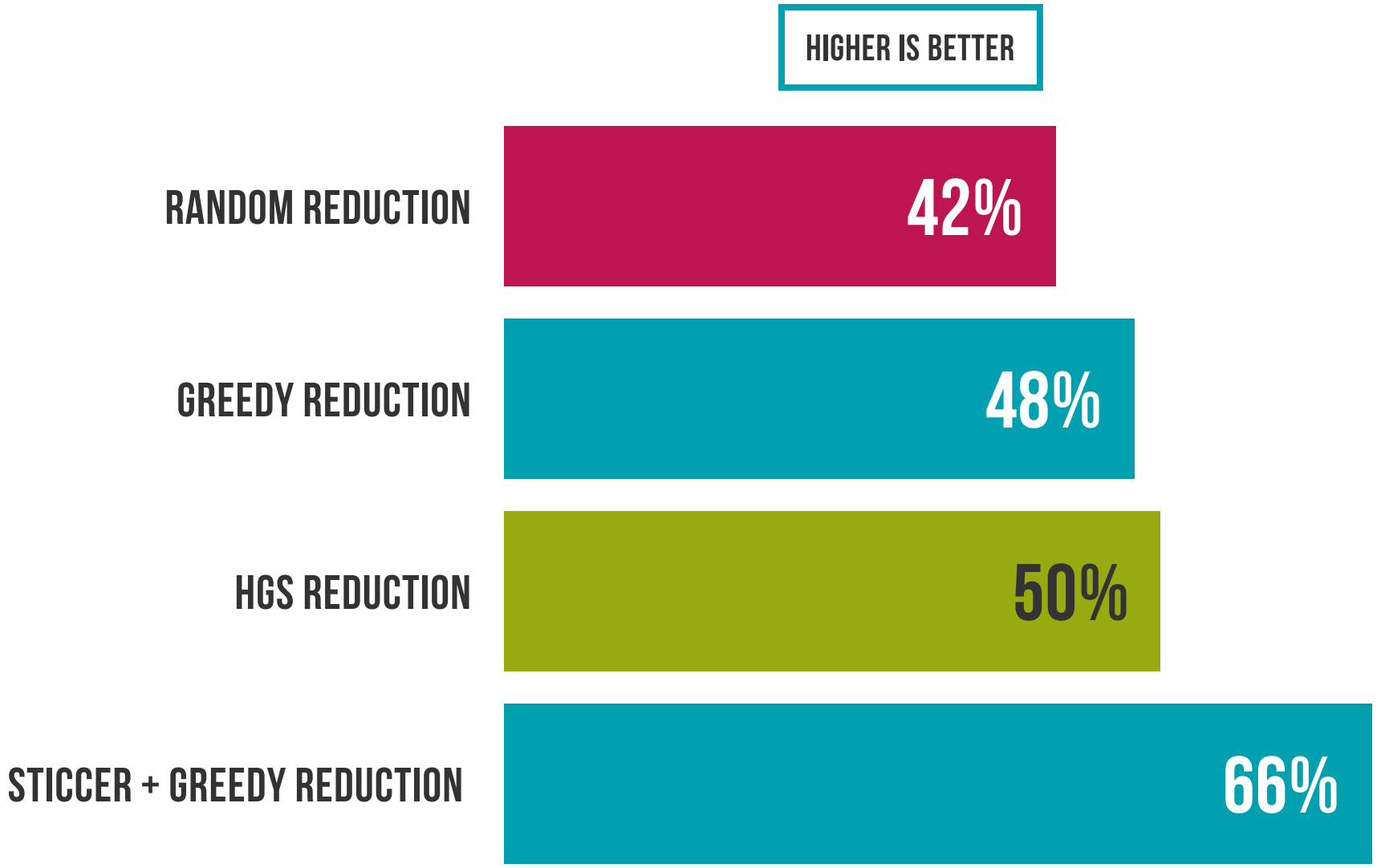
STEP 1: GENERATING TEST DATA

```sql
CREATE TABLE person (
    id int not null,
    last_name varchar(45) not null,
    first_name varchar(45) not null,
    gender varchar(6) not null,
    date_of_birth date not null,
    PRIMARY KEY  (id),
    CHECK (gender IN ('Male', 'Female', 'Other'))
);
```

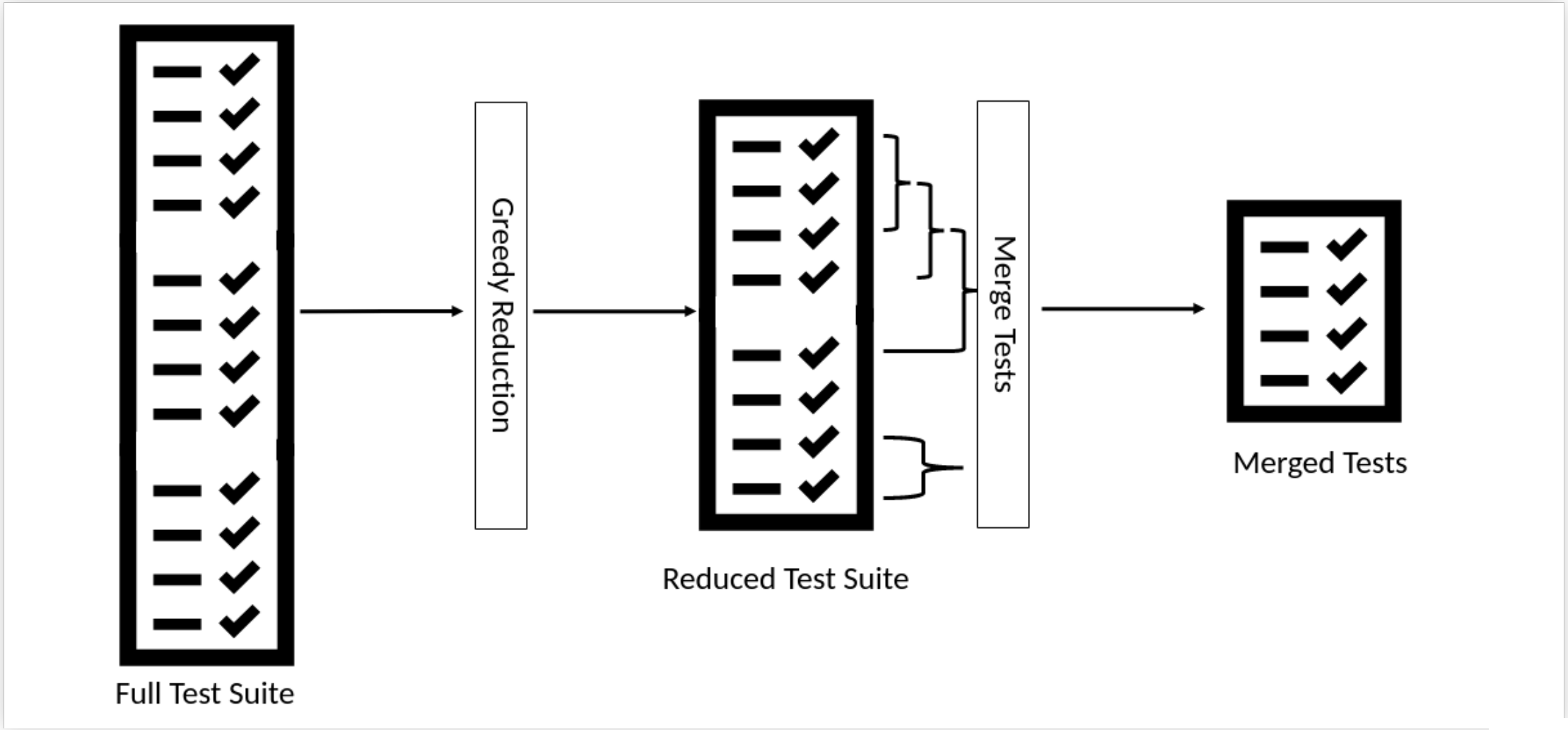
SchemaAnalyst

```sql
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-470, 'lmyp', '', 'Female', '1996-02-17');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'Uknown', 'Female', 'Male', '2009-05-28');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-416, 'qyvt', 'vwbtk', 'Uknown', '1996-11-22');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (NULL, 'ljleqrs', 'anusj', 'Uknown', '1991-05-24');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-61, NULL, 'Female', 'Uknown', '1995-07-25');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (959, 'atcusjct', NULL, 'Uknown', '1991-07-12');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (58, 'Uknown', 'waphctipj', NULL, '2008-09-03');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-45, '', 'hwssnyss', 'Female', NULL);
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-458, '', 'Female', 'Male', '2008-06-10');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (414, 'sflk', 'hkn', 'Female', '2000-01-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (0, 'ib', 'edvbewwyg', 'Uknown', '1992-03-17');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (54, 'Uknown', 'Male', 'xicbaf', '2012-04-03');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-653, 'dqikrgp', '', 'Male', '2000-01-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-156, 'ddnwmwdjv', 'utcwxgk', 'Uknown', '2000-01-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-114, 'jdtdu', 'Uknown', 'Uknown', '1998-06-14');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (0, 'pg', 'djdrua', 'Male', '1996-10-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-83, '', 'lvcykgb', 'Female', '2000-01-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (432, '', 'sknbueyq', 'Uknown', '2007-01-27');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (543, '', 'Uknown', 'Male', '2008-10-10');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01');
INSERT INTO "person"("id", "last_name", "first_name", "gender", "date_of_birth")
    VALUES (-435, 'vjiv', '', 'Male', '1998-03-01');
```

STEP 2: REDUCE TEST SUITE (PRIOR WORK)



HOW DOES STICCER WORK?

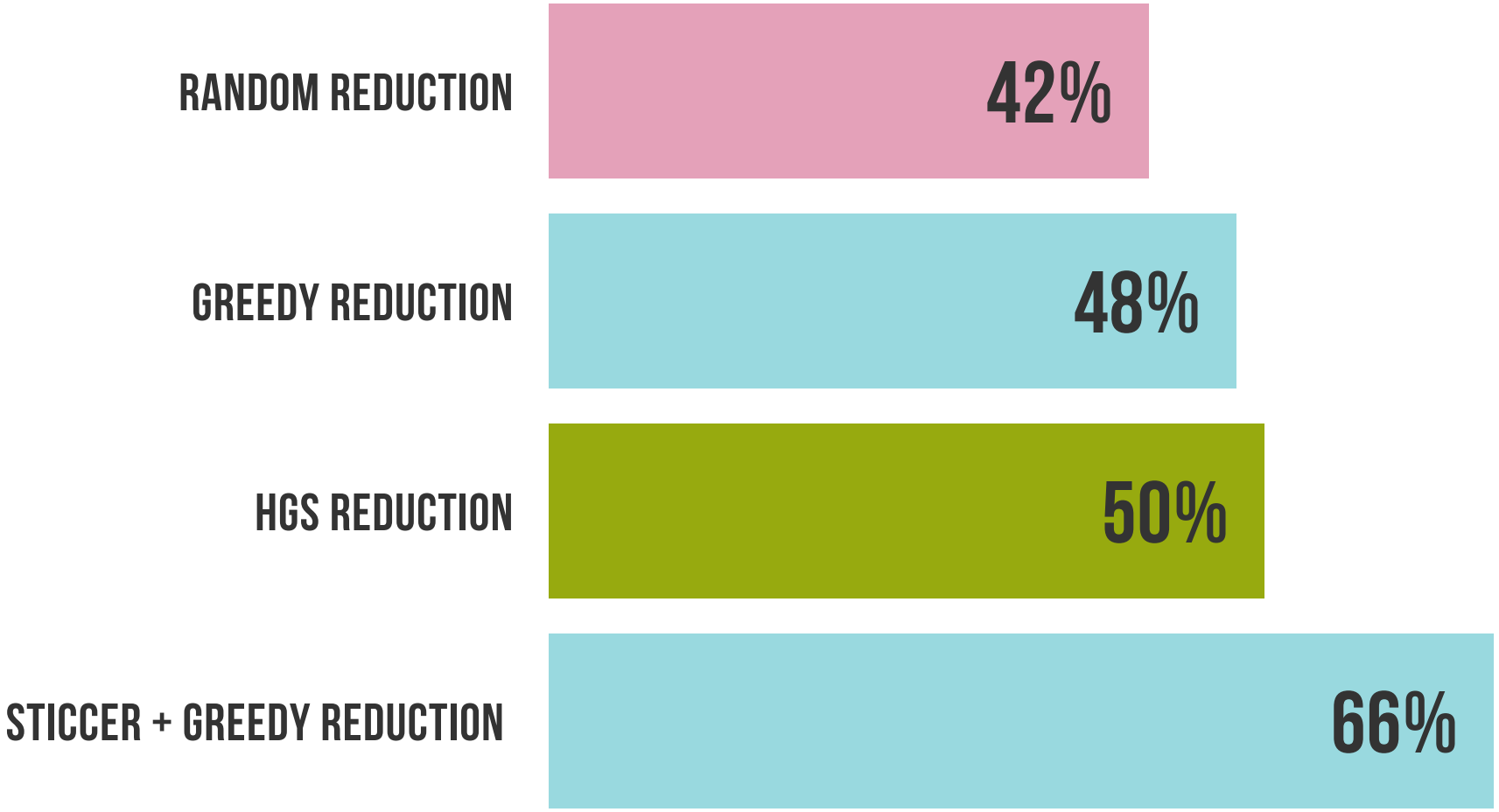


```
@Test
public void test17() throws SQLException {
    // prepare the database state
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
        ") VALUES (" +
        "    -585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01'" +
        ");"));

    // execute INSERT statements for the test case
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
        ") VALUES (" +
        "    -83, '', 'lvcykgb', 'Female', '2000-01-01'" +
        ");"));
}

@Test
public void test18() throws SQLException {
    // prepare the database state
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
        ") VALUES (" +
        "    -585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01'" +
        ");"));

    // execute INSERT statements for the test case
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
        ") VALUES (" +
        "    432, '', 'sknbueyq', 'Uknown', '2007-01-27'" +
        ");"));
}
```

```
@Test
public void test19() throws SQLException {
  // prepare the database state
  assertEquals(1, statement.executeUpdate(
      "INSERT INTO \"person\"(" +
      "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
      ") VALUES (" +
      "    -585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01'" +
      ");"));

  // execute INSERT
  assertEquals(1, sta
      "INSERT INTO \"pe
      "    \"id\", \"las
      ") VALUES (" +
      "    543, '', 'Uknown
      ");"));
}

@Test
public void test20() throws SQL
  // prepare the database sta
  assertEquals(1, statement
      "INSERT INTO \"perso
      "    \"id\", \"las
      ") VALUES (" +
      "    -585, 'dd
      ");"));

  // execute INSERT statements for the test case
  assertEquals(1, statement.executeUpdate(
      "INSERT INTO \"person\"(" +
      "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
      ") VALUES (" +
      "    -435, 'vjiv', '', 'Male', '1998-03-01'" +
      ");"));
}
```

```java
@Test
public void test17() throws SQLException {
  // prepare the database state
  assertEquals(1, statement.executeUpdate(
      "INSERT INTO \"person\"(" +
      "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
      ") VALUES (" +
      "    -585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01'" +
      ");"));

  // execute INSERT statements for the test case
  assertEquals(1, statement.executeUpdate(
      "INSERT INTO \"person\"(" +
      "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
      ") VALUES (" +
      "    -83, '', 'lvcykgb', 'Female', '2000-01-01'" +
      ");"));

  // execute INSERT statements for the test case
  assertEquals(1, statement.executeUpdate(
      "INSERT INTO \"person\"(" +
      "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
      ") VALUES (" +
      "    432, '', 'sknbueyq', 'Uknown', '2007-01-27'" +
      ");"));
}
```

WHAT ABOUT HYBRIDIZING HGS WITH STICCER?



COMPUTATIONAL STUDY RESEARCH QUESTIONS

1

REDUCTION EFFECTIVENESS.

How does STICCER-HGS compare at reducing test suites to STICCER-GRD, HGS, and Greedy?

2

FAULT FINDING CAPABILITY.

Fault-finding capability of test suites reduced by STICCER-HGS compare to those reduced by STICCER-GRD, HGS, and Greedy

3

REDUCTION AND MUTATION ANALYSIS RUNTIME.

Comparing STICCER-HGS and STICCER-GREEDY reduction and mutation analysis timing.

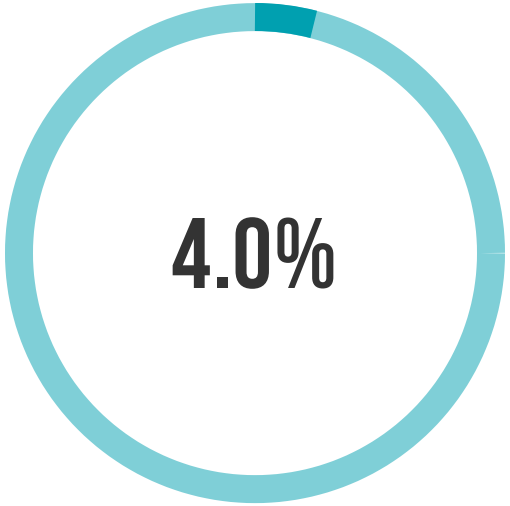
COMPUTATIONAL METHODOLOGY

1. 34 RELATIONAL DATABASE SCHEMAS
2. TWO TEST DATA GENERATION - AVM-DEFAULTS & DOMINO
3. DBMS: SQLITE
4. MUTATION ANALYSIS - ADDING, REMOVING, AND EXCHANGING INTEGRITY CONSTRAINTS
5. RECORDED COVERAGE, REDUCTION AND MUTATION TIME, AND MUTATION SCORES
6. COMPARED GREEDY, HGS, STICCER+GREEDY, AND STICCER+HGS REDUCTION METHODS

RQ1: REDUCTION EFFECTIVENESS - NUMBER OF TESTS

RQ1: REDUCTION EFFECTIVENESS - NUMBER OF INSERTS

RQ2: FAULT FINDING CAPABILITY - DETECTION DIFFERENCE



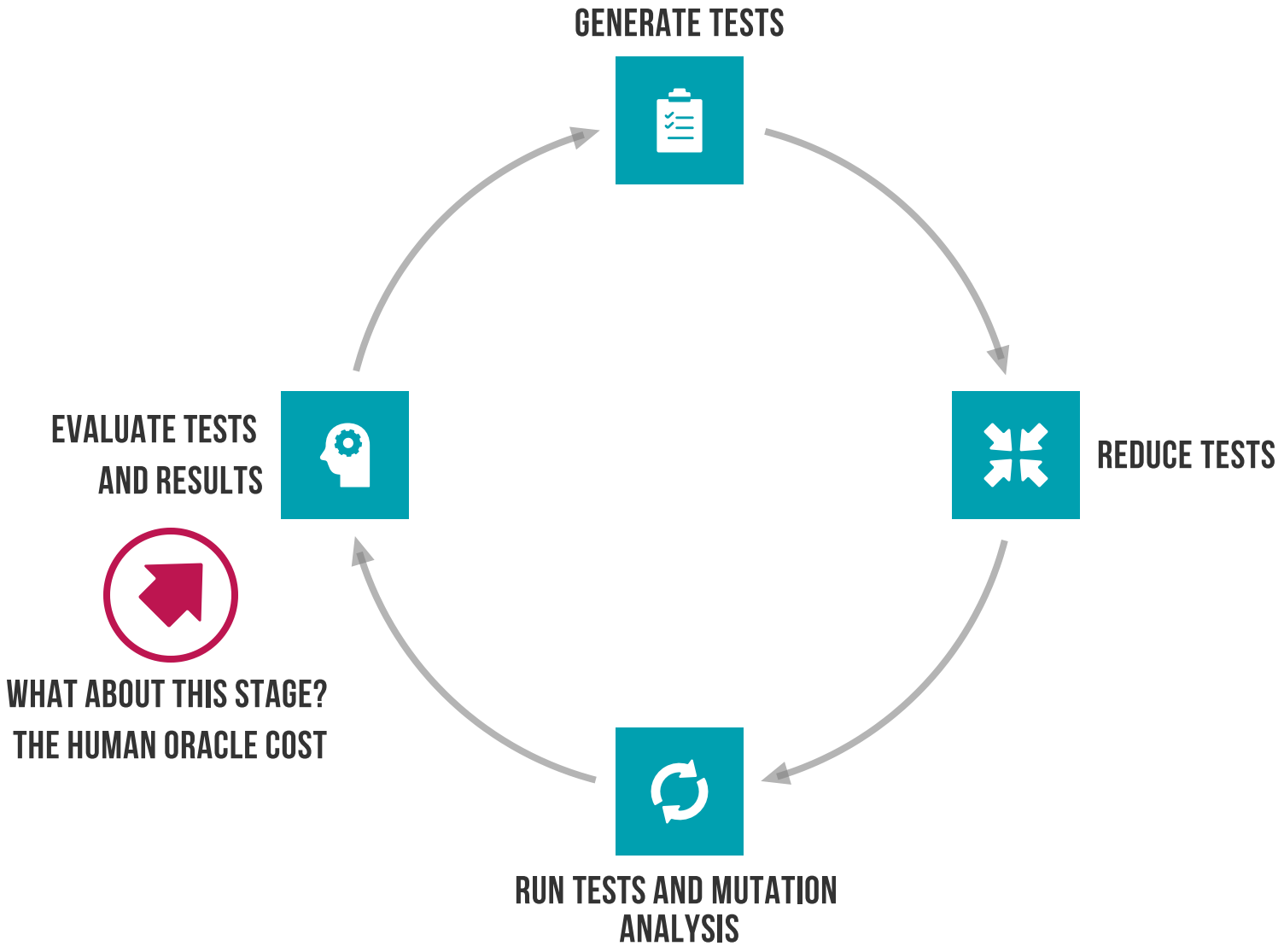
STICCER+HGS

AVM-D-generated suites did incur decreased scores, but only for *seven* schemas and not > 4%

RQ3: REDUCTION AND MUTATION ANALYSIS RUNTIME

1. STICCER+HGS IS MUCH FASTER FOR SMALLER SCHEMAS
2. STICCER+GREEDY IS FASTER WITH LARGER SCHEMAS
3. GREEDY (2 MIN) IS MUCH FASTER THAN HGS (11 MIN) SAVING MINUTES

AUTOMATICALLY GENERATING TESTS



HGS REDUCED TEST SUITE

```
@Test
public void test17() throws SQLException {

    // prepare the database state
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
        ") VALUES (" +
        "    -585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01'" +
        ");"));

    // execute INSERT statements for the test case
```

```
public void test18() throws SQLException {

    // prepare the database state
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
        ") VALUES (" +
        "    -585, 'ddnwmwdjv', 'djdrua', 'Uknown', '1998-03-01'" +
        ");"));

    // execute INSERT statements for the test case
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
        ") VALUES (" +
        "    432, '', 'sknbueyq', 'Uknown', '2007-01-27'" +
        ");"));
}
```

STICCER+HGS = MERGED TEST SUITE

```
@Test
public void test17() throws SQLException {
    // prepare the database state
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
```

```
        ") VALUES (" +
        "    -83, '', 'lvcykgb', 'Female', '2000-01-01'" +
        ");"));

    // execute INSERT statements for the test case
    assertEquals(1, statement.executeUpdate(
        "INSERT INTO \"person\"(" +
        "    \"id\", \"last_name\", \"first_name\", \"gender\", \"date_of_birth\"" +
        ") VALUES (" +
        "    432, '', 'sknbueyq', 'Uknown', '2007-01-27'" +
        ");"));
}
```

CAN HUMAN TESTERS EFFECTIVELY INSPECT REDUCED VERSIONS OF AUTOMATICALLY GENERATED SQL TEST SUITES?

HUMAN STUDY RESEARCH QUESTIONS

1 TEST INSPECTION ACCURACY

How accurate are humans at inspecting STICCER-HGS test suite compared to HGS?

2 TEST INSPECTION DURATION

How long does it take for humans to inspect STICCER-HGS test suites compared to HGS?

HUMAN STUDY METHODOLOGY

FOUR SCHEMAS

With seeded-faults to fail many INSERTs

TWO TEST DATA GENERATORS

DOMINO (random values) & AVM (default values)

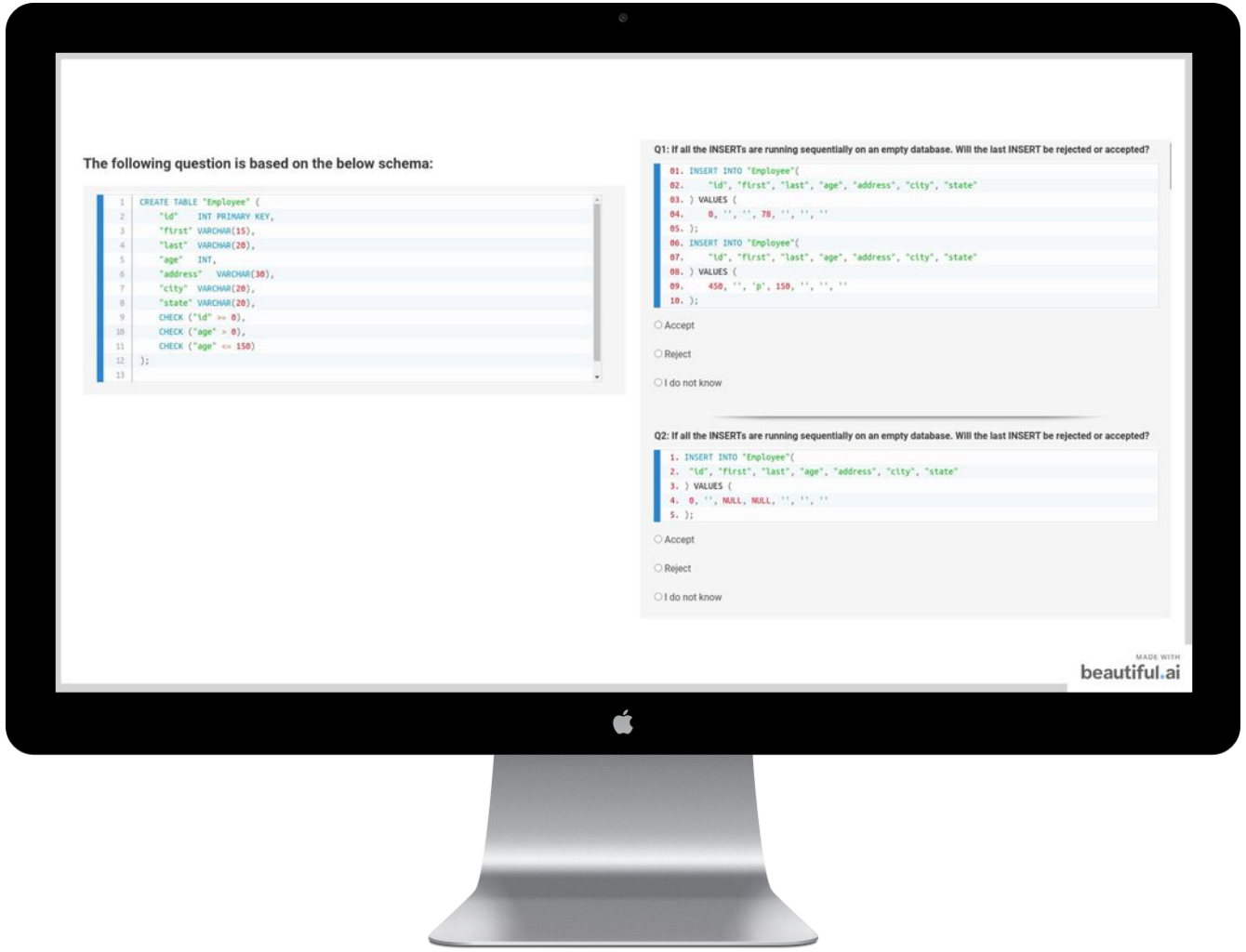
TWO REDUCTION METHODS

STICCER+HGS & HGS

25 PARTICIPANTS

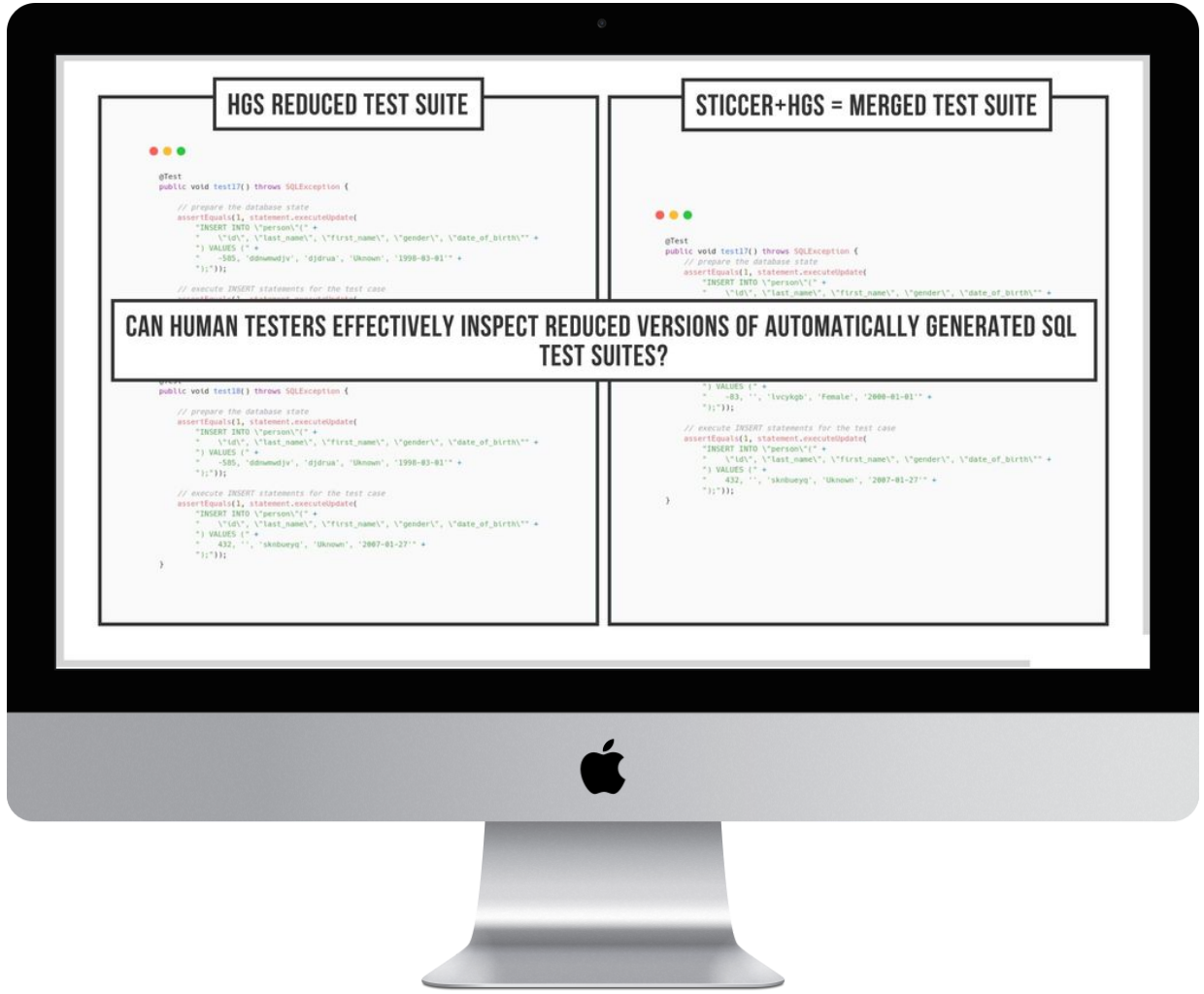
Students - Undergrads and PhDs

WEB-BASED QUESTIONNAIRE



- THE ORIGINAL & NON-FAULTY SCHEMA
- TESTS GENERATED ON THE FAULTY SCHEMA
- PARTICIPANTS ARE ASKED TO SELECT THE REJECTED INSERTS
- WE MEASURED TIMING AND SCORES

HUMAN STUDY RESULTS



STICCER-HGS'S ACCURACY GAVE IT NO CLEAR ADVANTAGE

PARTICIPANTS WERE FASTER AT INSPECTING THE SMALLER TEST SUITES REDUCED AND MERGED BY STICCER-HGS

CONCLUSION & FUTURE WORK

github.com/schemaanalyst/schemaanalyst

COMPUTATIONAL STUDY

- Neither STICCER-GRD nor STICCER-HGS are a strictly dominant method
- No significant benefit to hybridizing STICCER with HGS instead of Greedy

HUMAN STUDY

- Participants manually inspect reduced test suites and answer questions about their behavior
- Compared HGS to STICCER-HGS
- STICCER-HGS may help humans to perform test inspection faster, but not always more accurately

FUTURE WORK

- Other reduction techniques with STICCER
- Further human study with professionals
- Improve reduction efficiency